MANUAL OF BOTANY

GENERAL INTRODUCTION

THE science of Botany is concerned as fully as possible with everything that has reference to plants, either in a living or in a fossil state. It investigates their nature, their internal structure, their outward forms; the laws by which they are enabled to grow and propagate themselves; and their relations to one another, and to the other bodies by which they are surrounded. As a science, therefore, it is of vast extent, and one which requires for its successful prosecution the most careful and systematic study. We may look upon it as including several departments, which can be examined separately. It is very important to bear in mind that the objects of our study either are or have been living organisms, and to keep this fact prominently before us, whatever aspect of the plant may be temporarily occupying our thoughts. Bearing it in mind, we may regard especially the peculiarities of outward form which plants present; some of extreme simplicity and of microscopic dimensions, globular or cylindrical in shape, and consisting of only a single vegetable cell, with no differentiation of parts; others strings of cells, others flat plates, others of considerable substance, showing various parts, each with its own individuality. Such a section of the study is known as Morphology. We may again study the organism from the point of view of its internal structure, without reference to its form. We deal in this connection with structural units of plants; the vegetable cell as an individual, and the combinations of cells to form the filaments, plates, or masses of which the plant consists; tracing the various modifications of cell structure, the alterations in their forms, and the ways in which they are arranged together in the various parts of the organism: this forms the department of Vegetable Anatomy or Histology. Again, we may try to realise more clearly the life of the plant, and study the way in which it carries out its various vital processes, and reacts to its environment. This section is known as Vegetable Physiology. Another department is Taxonomy, which considers plants in their relationship to each other, and includes a knowledge of the principles upon which they may be classified. This is generally known as Systematic Botany. Geographical Botany, again, deals with the distribution of plants over the surface of the earth at the present time, and investigates the causes of such distribution. Palæophytography, or Fossil Botany, considers the nature and distribution of plants through the past ages of the earth's existence, and describes the structure of those found in a fossil state in the different strata of which the earth is composed. The first four departments only are those that come within the scope of the present work; the latter two being of too special and extensive a nature to be treated of in this Manual. There are also several sections of what may be called Applied Botany, which are founded on a knowledge of the above departments, such as Descriptive Botany, Vegetable Materia Medica, Agricultural, Horticultural, and Economic Botany, but to these special works are commonly devoted.

In studying the subject the relationships between these different sections must be borne in mind. The student will soon understand that all questions of form and structure must be examined from the point of view of function, and will learn that all differentiation of the plant body has been determined by division of labour, or allocation of particular function to particular parts.

If we consider the case of an ordinary tree, we find it incapable of locomotion and fixed in some particular spot of earth. In such a situation it has to maintain its position and take everything necessary for its nutrition from either the soil or the air which surround its different parts. The greater the amount of both with which it comes into relationship, the easier it will be for it to secure these ends. Hence the advantage of its great subdivision of both underground and sub-aerial parts. Similar considerations throw a great light upon the details of its superficial and internal structure.

BOOK I

MORPHOLOGICAL BOTANY

CHAPTER I

GENERAL MORPHOLOGY OF THE PLANT

THE simplest plants, such as the Red Snow (*Protococcus*), or *Pleurococcus*, consist of a single piece of living substance, or *cell* as it is termed, which in form is more or less spherical or oval. New plants are formed by the division of this cell into two, sometimes of equal, sometimes of unequal dimensions. In *Protococcus* the cells separate almost as soon as formed, while in *Pleurococcus* they remain bound together for a longer or shorter period by an environing capsule of gelatinous matter, the result of a modification of a limiting membrane or cell-wall. In plants a little more complex in structure we find the cells still all alike, but instead of being separated and each becoming a distinct plant, or forming a small colony of cells, they are joined end to end and form a many-celled filament which is either straight or variously curved, as in *Oscillaria* (*fig.* 2). The most lowly of these plants—so far at least as is known—multiply by division of their cells only. A little higher in the scale we meet with

FIG. 1.

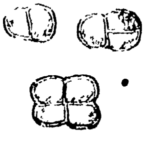


FIG. 2.

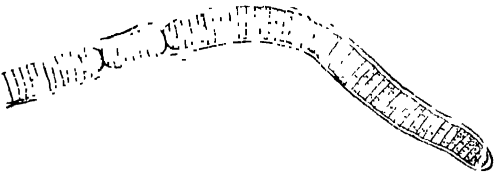


Fig. 1. *Pleurococcus vulgaris*: cells dividing (× 600).
Fig. 2. Portion of a filament of *Oscillaria* (× 750).

plants in which, while certain of their cells perform the function of nutrition, others are set apart for the purpose of reproduction. In the common Moulds, such as *Mucor* (*fig.* 3) or *Eurotium* (*fig.* 4), the cells which serve as organs of nutrition are elongated simple or branched filaments, termed *hyphæ*, which lie upon the surface and burrow in the mass of the substance furnishing the plants with food; while others, destined to reproduce the individual, are developed in globular cavities (*sporangia*), as in *Mucor* (*fig.* 3); or are arranged in necklace-like branches at the end of special filaments, as in *Eurotium* (*fig.* 4).

Fig. 3.

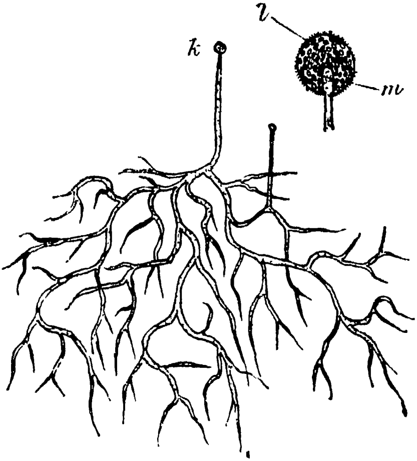


Fig. 3. A species of mould (*Mucor*) with branched mycelium composed of hyphæ, and bearing two sporangia *k*, shown more highly magnified at *l*.

Yet a little higher in the scale of vegetable life we find the cells so combined as to form flattened expansions (*fig.* 5), or solid axes (*fig.* 6), as well as special organs of reproduction (*fig.* 5, *t*, *t*). But the cells are all more or less alike, so that no true distinction can be drawn between the often very different-looking parts we meet with in such plants as a seaweed or a mushroom. Such a combination of similar cells, whatever the precise form may be, which presents no differentiation of leaf and stem, is called a *thallus* or *thallome*. The plants which are commonly known as *Algæ* and *Fungi* usually possess such a plant body, and they have been grouped together to form a division of the vegetable kingdom which bears the name *Thallophyta* in consequence.

From the Thallophyta by various intermediate stages, through a division of plants called *Liverworts*, we arrive at another group the *Mosses*. In the lower forms of the Liverworts, e.g. *Marchantia* (*fig.* 7), we have a green flat thallus-like stem bearing upon its under-surface scale-like appendages, which botanists have considered to be the first representatives of true leaves. In the higher forms, as *Jungermannia* (*fig.* 8), the stem and leaves are both more highly developed.

FIG. 4.

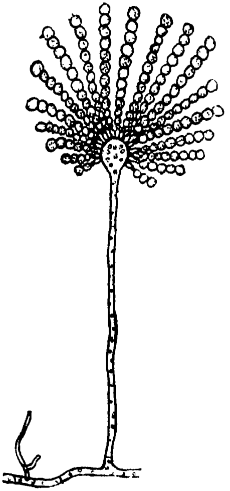


Fig 4. Another mould (*Eurotium*) with reproductive cells arranged in rows on a special branch.

FIG. 5.

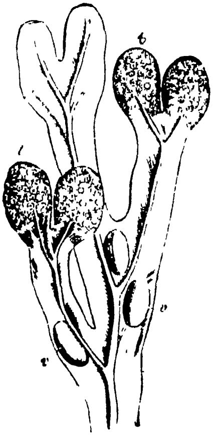


Fig. 5. Thallus or thallome of the common Bladder Seaweed (*Fucus vesiculosus*). *t*, *t*. The fructification. *v*, *v*. Bladders containing air.

With the exception of some of the higher Mosses, such as *Polytrichum*, all the plants so far described are composed mainly of cells which approach more or less closely to the spherical or oval form, or which, if elongated, are thin-walled and commonly flexible. They are hence often termed *Cellular Plants*, in contradistinction to others whose composition is much more complicated, causing them to be called *Vascular Plants*. These are so named on account of their possessing, in addition to such cells (which are called *parenchymatous*), elongated, generally thick-walled cells, termed *prosenchymatous* cells, or *fibres*, and also in most cases variously formed tubular organs which are known as *vessels*. The distinction between cellular and vascular plants is not, however, absolute, as certain of the Algæ afford undoubted instances of the occurrence of particular vessels known as sieve-tubes, much like forms met with in the highest flowering plants. In the higher Mosses, e.g. *Polytrichum* (*figs.* 9 and 10), the stems often contain elongated cells, whose walls are so thickened and chemically changed that they differ little from the true wood-cells met with in the more highly developed plants. Correlated with this greater development of the organs of nutrition we find the reproductive apparatus showing a more complex structure, as will be hereafter described. The Liverworts and Mosses are, however, destitute of vessels, such as exist in the next and all the higher groups of plants.

FIG. 6.

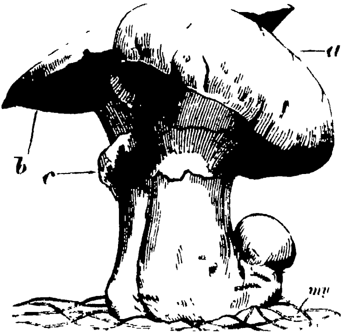


Fig. 6. The common Mushroom (*Agaricus campestris*). There are three receptacles (*fructification*), rising from the mycelium, *my*, below: one young and nearly globular, and two mature. *a*. Pileus. *b*. Lamellæ. *c*. Annulus.

FIG. 7.

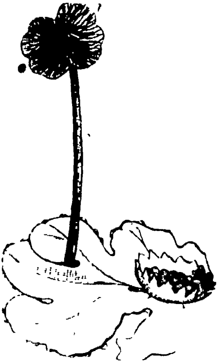


Fig. 7. A portion of the flat thallus-like stem of *Marchantia polymorpha*, showing an antheridial receptacle, *r*, supported on a stalk, *s*.

FIG. 8.

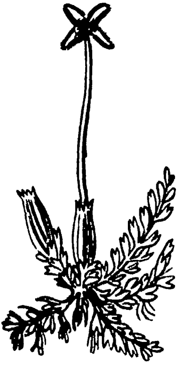


Fig. 8. *Jungermannia bidentata*. The stem is creeping, and bears numerous small imbricated leaves.

Still ascending, we find in the *Ferns* (*fig.* 13), *Horsetails* (*fig.* 12), *Pepperworts*, *Club-mosses* (*fig.* 11), and *Selaginellas* a continued advance in complexity of structure; vessels of different kinds make their appearance, and the stems are frequently of considerable size and height. *Calamites*, an order of extinct plants allied to the Horsetails, which were extremely abundant during the formation of our coal measures, appear to have reached the height of our loftiest trees; while at the present day in the tropics and warmer parts of the earth Ferns frequently attain the height of twenty feet (*fig.* 14), and

FIG. 9.

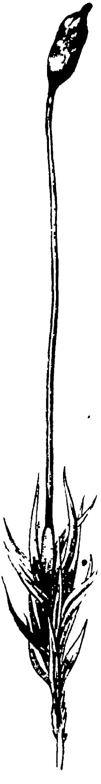


FIG. 10.

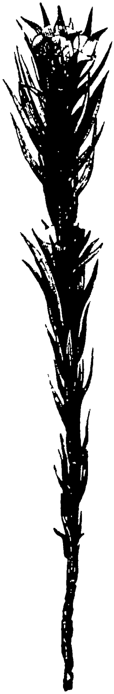


FIG. 11.

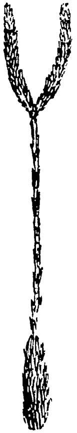


FIG. 12.

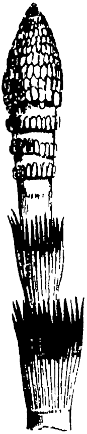


Fig. 9. Plant of the Hair-moss (*Polytrichum commune*), with leaves, stem, and sporogonium.——*Fig.* 10. Plant of the same, with stem and leaves, and terminated by the male organs (*antheridia*).——*Fig.* 11. The common Club-moss (*Lycopodium clavatum*).——*Fig.* 12. Termination of fertile branch of the Great Water Horsetail (*Equisetum maximum*).

sometimes even as much as forty feet. Such Ferns bear on their summits a large tuft of leaves, or, as they are commonly called, *fronds*, a term applied to leaves which, like those of Ferns, bear organs of reproduction.

FIG. 13.

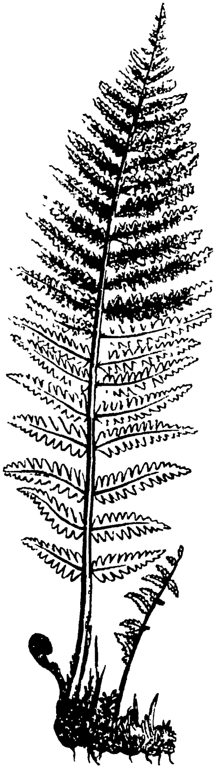


Fig. 13. The Male Fern (*Aspidium Filix-mas*) (¼ natural size).

The plants which have been mentioned so far have been called *Cryptogams, or Flowerless Plants.* As we shall see later, this designation is not properly applied to all of them. They are especially and more fitly characterised by not producing the special structures known as *seeds*.

All plants above the Cryptogams, from possessing evident flowers, are termed *Phanerogams*, or *Flowering Plants*. These latter plants are marked off from all the lower forms by bearing seeds.

The Phanerogams present two well-marked divisions, called respectively the *Angiospermia* and *Gymnospermia*: the former including those plants in which the seeds originate in a case called an *ovary* (*fig.* 398, *o*, *o*); and the latter, such plants as the Fir and Larch, in which they do not. In the Phanerogams we have the highest and most perfect forms of plants.

A survey of the forms presented by the various plants constituting the vegetation of the globe shows us thus an extraordinary variety in external shape, in actual dimensions, and in peculiarities of internal structure. The simplest with which we are familiar exhibit only a roundish or ovoid body, with no differentiation of parts, consisting only of a minute mass of living substance, or protoplasm, which may or may not be surrounded by a definite limiting membrane or cell-wall. Each plant is said to consist of a single cell. Generally, with larger size we find the living substance consisting of a number of cells, separated by partition-walls.

These are, in some cases, arranged in strings or filaments; in others they form flat plates; in yet others they constitute masses of great size and much-divided shape. The plant body, in the latter case, evidently consists of various parts, which are spoken of as its *members*.

The study of the life history of most plants shows us further that each may have different forms at different periods of its life. In many of the lower plants this *polymorphy*, as it is called, is very

FIG. 14.

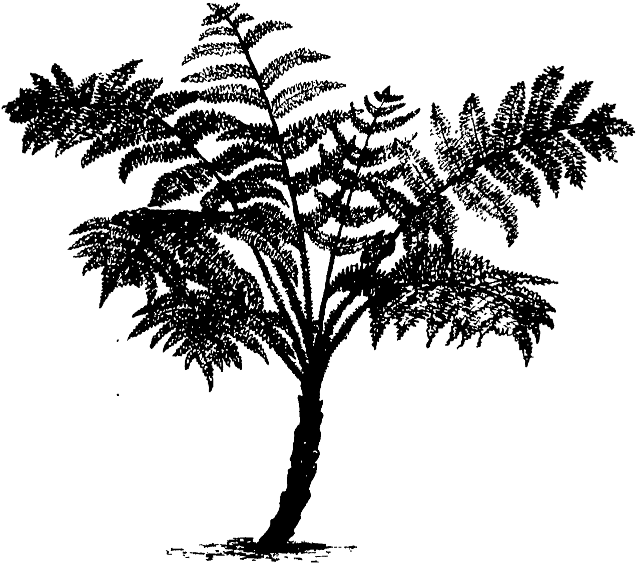


Fig. 14. A Tree Fern.

varied; but in the case of organisms higher in the scale, it is found there is a tendency to assume only two forms, which recur in constant alternation with each other. Each form is characterised by producing a special kind of reproductive organs, and bears a name indicating their nature. The common Fern is perhaps the most easily studied illustration of this. In the form usually recognised as the Fern plant, the plant body is found to carry out the process of reproduction by certain cells which are known as *spores*. These are *asexual* reproductive cells: that is, each is capable by itself of producing a new individual. This form, as it bears only spores, is known as the *sporophyte*, or spore-bearing generation. The other form, a little green flattened body, generally about a quarter of an inch in diameter, called the *prothallus* (*fig.* 15), produces *sexual* organs, which give rise to reproductive cells of two kinds known as *gametes*. Neither of these can by itself give rise to a new organism, but after a process of fusion of two of them, one of each kind, the resulting cell can originate such a development. The form of the individual arising from the spore is always a *prothallus*, and that which is developed

FIG. 15.

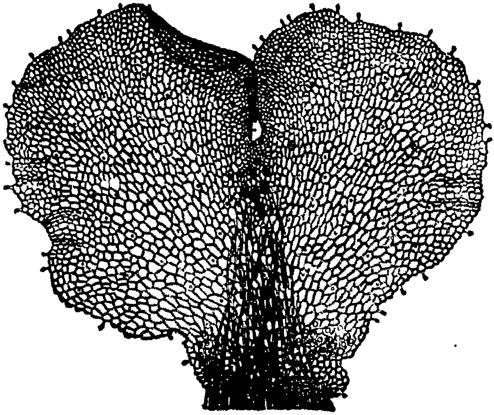


Fig. 15. Prothallus (gametophyte) of Fern (× 10). After Kny.

from the fused gametes of the latter, which unite to form a cell called the *oospore* or *zygote*, is the new *Fern*.

In some plants the sexual cells are apparently all alike, but in most they differ in shape, size, power of motion, &c. Whether similar or dissimilar, they are known as *gametes*, and the phase of the plant which bears them is consequently called the *gametophyte*.

In many plants the sporophyte produces two kinds of spore, each of which gives rise to a special form of gametophyte. In such cases the two kinds of spore differ very greatly in size.

In all the higher plants the two forms regularly alternate, the sexual cells of the gametophyte giving rise to the sporophyte, and the spores of the latter reproducing the gametophyte—the life history of each plant so exhibiting what is known as an *alternation of generations*.

In the lower forms, among the Algæ and Fungi, another variety of alternation is met with. Their gametophytes, in many cases, bear asexual cells as well as gametes, and frequently the gametes are not developed, so that many asexual generations often follow each other before a sexually produced form recurs.

The asexual cells which arise upon the gametophyte are called *gonidia*. They do not differ essentially from spores.

Among the lower plants the gametophyte is usually the more prominent of the two forms described. In the Mosses the two are almost equal in degree of development. The gametophyte is the so-called moss plant, and consists of an axis furnished with numerous leaves. The sporophyte consists of a swollen head or capsule, supported on a stalk of variable length, and remaining attached to the gametophyte. It forms the body which is often somewhat loosely spoken of as the fruit.

Above the Mosses the tendency is to greater development of the sporophyte and retrogression of the gametophyte. In the Ferns and the higher Cryptogams the plant known under the ordinary name of *Fern*, *Horsetail*, or *Club-moss* is the sporophyte, and the gametophyte is a small structure, consisting of only a plate of cells, or a small tuber-like mass, and showing little or no segmentation of its body. In the flowering plants the retrogression of the gametophyte is still more marked; they possess two kinds of spore, each of which gives rise to an appropriate gametophyte, one bearing male, the other female gametes. The gametophytes produced by the small spores, or *microspores*, which are often spoken of as *pollen grains*, consist of long tubular outgrowths, which during their development bore their way into the structures among which the large spore and its gametophyte are found. The gametophyte arising from the large spore, or *megaspore*, or *embryo sac*, consists, in one large section of the flowering plants, the Gymnosperms, of a cellular mass which is developed inside the spore, and completely fills it. In the other section, the Angiosperms, it is similarly hidden in the interior of the spore, but it consists of only a few cells, some of which are not even furnished with cell-walls.

Above the Thallophyta the cell produced by the fusion of the gametes gives rise to the new individual while still attached to the gametophyte, so that the sporophyte appears to spring out of the latter. The spores, on the other hand, of whatever kind they may be, are generally set free from the sporophyte, so that the gametophyte appears as an independent structure. As already mentioned, this is not the case with the Phanerogams. These produce two kinds of spore: the smaller ones only are set free, subsequently giving rise to the gametophyte or *pollen tube* which bears the male gametes; the larger ones remain always attached to the sporophyte, each producing its appropriate gametophyte in its interior, and ultimately leading to the formation of a special structure called the *seed*.

The body of the plant, whether gametophyte or sporophyte, may show various degrees of complexity of form. It may be evidently divisible into parts, or *members*, which may be all alike, or may be dissimilar; or, again, it may show hardly any such segmentation. In the great majority of cases the body consists of two dissimilar members, characterised by growth in opposite directions; these are then called the *root* and the *shoot*. Both of them generally exhibit appendages springing from the main body; but while those of the root are like the member from which they arise, those of the shoot may be of two kinds, some like, others unlike, that on which they are borne. Those which are like it are known as *branches*; those unlike it, *leaves*. We can distinguish between *thalloid* shoots and *leafy* shoots, according as branches only, or branches and leaves, can be recognised on the shoot. Roots almost always bear branches only, leaves occurring on them only under very exceptional circumstances. A further difference between the root and the shoot consists in the fact that the latter always bears the true reproductive organs. The part of the shoot which gives rise to the appendages is termed the *stem*, and the stem and main root together constitute the *axis* of the plant.

Plants which show a differentiation of their shoot into stem and leaves are called *Cormophytes*. The prominent form is in most cases the sporophyte, and the distinction between the two parts of its axis as to the direction of their growth can frequently be seen from the very commencement of its development. The cell formed by the fusion of the gametes, usually called the *oospore*, is first divided by a cell-wall, known as the *basal* wall, into two segments, of which the upper one, or *epibasal* cell, develops the shoot, and the lower, or *hypobasal* one, ultimately gives rise wholly or partially to the root. The primary root and the primary stem are thus always opposite to each other.

Those plants whose shoots show no segmentation into stem and leaf are known as *Thallophytes*, and the plant body is called a *Thallus*.

The thalloid shoot may be regarded as intermediate between a true thallophyte and a cormophyte.

The relative development of root and shoot may vary very greatly. In most of the lower plants the root is frequently of very small size and very simple structure. In the great group of Algæ or Seaweeds, in which the gametophyte is the prominent form, this member is never very greatly developed, though the shoot of the same plant may attain large dimensions. In some of the filamentous floating forms it can hardly be said to exist, being often only indicated by the single hypobasal cell persisting at the end of the filament, and this having only a very short duration. In the sporophyte of the higher cormophytes both root and shoot are well developed and much branched, the shoot being still relatively the greater.

The shoot usually shows much more differentiation than the root. Its axis, the stem, gives rise to branches and to leaves. The branches in turn may give origin to other branches, and these to others, thus forming an elaborate branch system. Each branch, like the main stem, also produces leaves. The leaves, on the other hand, though often very much branched, or compound, never bear other leaves.

In the higher cormophytes, in which the sporophyte is the prominent form, it produces special shoots for the purpose of bearing the reproductive cells or spores. Usually these cells are borne on special leaves, which are then called *sporophylls*. Sometimes these sporophylls very closely resemble the ordinary leaves, as in many Ferns; sometimes they differ from them very markedly in appearance and structure. The special shoot of which they are the leaves is then known as the *flower*, and the branch system constituted by the flowers is called the *inflorescence*. In most cases this is sharply marked off from the general branch system. The flowers have usually, besides the sporophylls proper, certain other external leaves which do not themselves bear spores.

In the lower plants, when the spores have become mature they are detached from the parent plant and germinate independently, giving rise to a separate gametophyte. In the flowering plants, where the spores are of two sizes, it is only the *microspores* or *pollen grains* which are so dispersed. The *megaspore*, or *embryo sac*, germinates in the *sporangium*, or *ovule*, and gives rise to its peculiar form of gametophyte within itself. By certain appropriate mechanisms the gametophyte arising from the pollen grain is brought into relation with that developed from the embryo sac, and the gametes from the two unite as in other cases to form an oospore. This fusion, which is known as the fertilisation of the oosphere or female gamete, is followed generally by a certain development of the neighbouring parts. Even when the gametophytes are developed apart from the sporophyte, the act of fertilisation is often attended with the same result. The body thus produced is known as the *fruit*. In the latter cases the fruit is altogether a development of the gametophyte; in the former, the parts which form it are derived from the sporophyte, to which the gametophyte remains attached. In this way, in the flowering plants, the fruit is developed from the central portion of the flower.

The consequence of the megaspore, or embryo sac, of the highest plants, always remaining in the sporangium, or ovule, and the gametophyte derived from it never having an independent existence, is the production of another structure, found at maturity usually within the fruit, and known as the *seed*. When the gametophyte has been developed it bears normally one sexual cell or gamete, known as the *oosphere*. This is fertilised by the male gamete while the whole gametophyte is still in the interior of the sporangium, and the oospore resulting from such fertilisation germinates at once, starting the growth of the new sporophyte This growth takes place at first within the sporangium, and proceeds for a longer or shorter period till the form of the new sporophyte is clearly indicated in its parts. Then the growth temporarily stops, and the sporangium with its contents becomes separable from the sporophyte. The sporangium or ovule has now become the *seed*, a structure which, from the peculiarities of development indicated, is confined to the flowering plants. It contains the new sporophyte, known as the *embryo*, besides enclosing the remains of the gametophyte which gave rise to the latter, and which may or may not constitute the greater part of the structure.

After the seed has been detached from the sporophyte it remains quiescent for a variable time, but under appropriate conditions the temporarily suspended development is resumed, and the new sporophyte soon attains an independent existence.

The formation of the seed is thus a special feature of those plants in which the megaspore does not become detached from the sporophyte, but develops *in situ*. This important peculiarity marks off the large class of Phanerogams or flowering plants from those below them in the scale of development. In such of the latter, known as the Cryptogams, as have megaspores the latter are always detached from the sporophyte, and therefore seeds are not produced.

If we compare the forms of the gametophyte and sporophyte in such plants as plainly possess both, we can notice that the gametophyte is usually a thallus, but is cormophytic in the larger Algæ, the Jungermannias (a family of the Liverworts), and in the Mosses. The sporophyte is but seldom recognisable among the Thallophytes, many of which indeed possess only a gamophytic form, but it is a thallus in such of the Algæ and Fungi as possess one. With few exceptions it is a cormophyte in all plants above the Mosses. In the higher plants it presents us with a series of members. We may distinguish the root and the shoot; the latter including various forms of branches and different kinds of leaves. Its most important members are the stem, the vegetative branches, the inflorescence, and the flowers; the leaves, some *foliage leaves*, others *sporophylls*: lastly the fruit and seed.

The gametophyte is seen at its best in the Algæ, Fungi, Liverworts, and Mosses. Here it may show root, stem, and leaf, or it may be only a thallus or a thalloid shoot. Above the Mosses it is gradually and progressively reduced, being never more than a thallus above this point, and gradually becoming less and less prominent, till at last it consists of only a few cells in the interior of the megaspore.

The vegetative members of the plant may now be considered in greater detail separately, the morphology of the special reproductive members being deferred to a succeeding chapter.

THALLOPHYTES.

The Thallus.

The thallus may consist of a single cell, or may be composed of many cells. It shows scarcely any distinction of parts or segmentation, and but little differentiation of its internal tissues. It is often possible to see a division into root and shoot, but in such cases the former is only very slightly differentiated and often consists of only a single cell of the embryo. There is never any particular difference of structure between them. When a thallus is composed of more than one cell it may be a filament or a collection of filaments, or a flat plate often only one cell thick, or a mass of some size. In the last two cases it may bear a number of hairs from any part of its surface. In some cases, as in *Volvox*, it is a spherical body capable of active movement carried out by special filaments or cilia, which move rapidly to and fro in the water in which the plant lives. It may be branched, certain branches being like the main body, and others specially modified to produce the reproductive organs.

The thallus is seen best in the lowest plants, where generally the whole plant body is of this description. It is the prominent form in most Fungi and Algæ; is that of the gametophytes of the Ferns and most other Vascular Cryptogams and of the Flowering Plants. The sporophyte is less frequently a thallus, but this is the case in such of the Algæ as possess one, and in a few exceptional Phanerogams; e.g. *Wolffia arrhiza*, *Lophogyne*, etc.

CORMOPHYTES.

For many reasons it is most advantageous to commence the study of the morphology of cormophytic plants with the most highly differentiated forms. These are to be met with in the great group of the Phanerogams, and in particular in the section known as the Angiosperms, to which all our ordinary plants with conspicuous flowers belong. The prominent form in these, as we have seen, is the sporophyte.

Fig. 16.

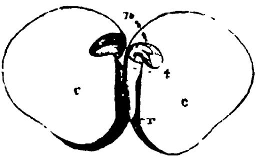


Fig. 17.

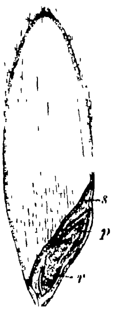


Fig. 16. Dicotyledonous embryo of the Pea, laid open (magnified). *r*. The radicle. *t*. The axis (*hypocotyl*), terminated by the plumule, *n*. *c*, *c* The cotyledons.——*Fig.* 17. Section of the fruit of the Oat. *p*. Plumule. *r*. Radicle. *s*. Scutellum.

If we examine the seed of one of these Angiosperms, *e.g.* that of the common Pea, we find it contains the embryo or young plant in a rudimentary form. This embryo is shown in *fig.* 16. It consists of a distinct central axis *t*, which is sometimes called the *tigellum*, the lower part of which is known as the *radicle*, *r*; the upper part, which bears two or three rudimentary leaves, is known as the *plumule*, *n*. This axis is united to, or bears, two fleshy masses, or lobes, which are its leaves or *cotyledons*, *c*. The part between the attachment of the cotyledons and the radicle is sometimes called the hypocotyledonary portion or *hypocotyl*, and the portion above the cotyledons, the epicotyledonary part or *epicotyl*. Plants, like the Pea, which bear two cotyledons, are grouped together to form a great class known as the *Dicotyledons*. In many seeds embryos are found which possess only one cotyledon. Such are the embryos of Grasses (*fig.* 17). These plants form another great group known as the *Monocotyledons*.

When such a seed as the Pea is placed under favourable conditions, its embryo begins at once to develop, the radicle growing in a downward direction, while the plumule extends itself upwards. We thus can distinguish between the two parts of the axis according to the direction of their growth. From the lower portion is formed the root system, from the upper portion the shoot, consisting of the stem and its appendages.

FIG. 18.

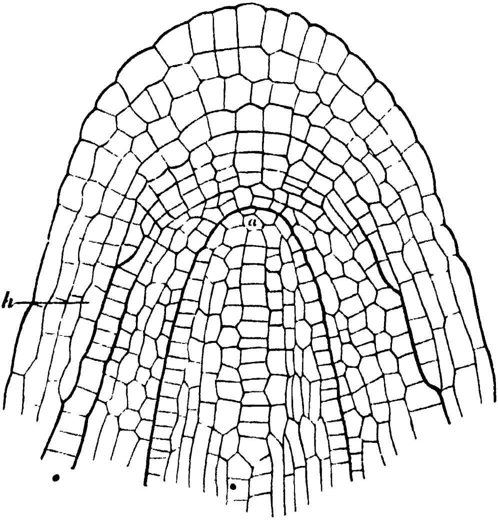


Fig. 18. Longitudinal section of the apex of a root of Buckwheat *a*. Growing point. *h*. Root-cap.

SECTION I.—THE ROOT.

The root is seen thus to be the descending axis of the plant. It usually attaches the plant to the substratum on which it grows and absorbs nutriment therefrom. It presents certain features which distinguish it at once from the stem; though it may branch repeatedly, it only bears such appendages as are like itself; it never bears true reproductive organs, and only under exceptional circumstances does it give rise to leafy shoots or leaves. Its growth takes place by increase of its substance immediately behind its apex, so that the growing region (*a*, *fig.* 18) is always internal and protected by a thin cushion or cap of tissue known as the *root-cap* (*h*, *fig.* 18; *r*, *fig.* 19). In those roots which grow in ordinary soil, the root is furnished, a little way behind the apex, with a number of very delicate outgrowths from the surface, which penetrate into the crevices between the particles of the soil, and come into very close relationship with them. These structures are known as the *root-hairs*; they are the structures through which absorption from the soil takes place. They are not distributed over the whole surface, but only occupy a small space not far behind the growing point (*fig.* 20). These hairs are not to be regarded as *appendages*, in the sense already mentioned, for all parts of the plant agree in being able to give rise to similar structures. They are only outgrowths of the external covering.

FIG. 19.

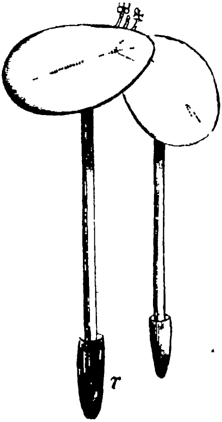


FIG. 20.

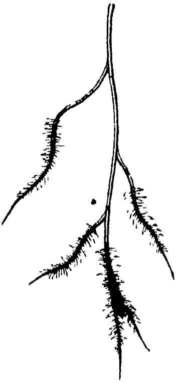


Fig. 19. Young plant of Lemna (*Duckweed*). *r* Root cap.—*Fig.* 20. Ultimate branches of a root, showing position of root-hairs.

The direct prolongation of the radicle downwards forms what is known as the *primary* root. This may grow to a great size, persisting through the life of the plant. It is usually tapering in form, and bears numbers of branches, which may themselves branch repeatedly and so give rise to a large root-system. When the primary root is thus persistent and stronger than its branches, it forms what is known as a *tap-root*. On the other hand, it is not unusual for the primary root to develop only to a slight extent, and to be speedily surpassed in vigour by its branches.

The branches of the primary root, like the latter, always have their apices covered by a root-cap. They arise, with very few exceptions, within the tissues of the primary root, and in their growth bore their way outwards through its external layers. They are known as *secondary* roots, and they in turn produce *tertiary* roots, and so on. In their order of development each branch normally arises nearer to the apex than the one before it, so that the youngest is always the nearest to the tip. This mode of origin is known as *acropetal succession.*

FIG. 21.

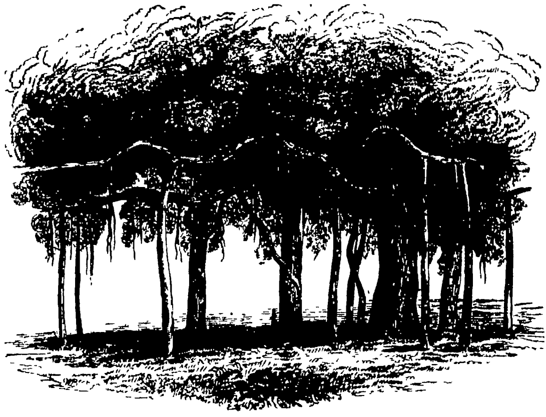


Fig 21. The Banyan-tree (*Ficus indica*)

It is not confined to roots, but is a feature of branching in general.

Occasionally, however, roots arise at other places than their normal point of origin. Such are known as *adventitious* roots. Examples may be seen in the roots produced upon the stems of the Ivy and other plants, by which they are enabled to attach themselves to the surfaces over which they are climbing. Very frequently roots of this description are developed from injured surfaces, as in the case of those plants which are propagated by means of cuttings. When a young twig of a Geranium is severed from the stem and its cut end embedded in moist soil, it shortly puts out these adventitious roots from the cut surface and develops into a new Geranium plant. Adventitious roots can also be made to arise from leaves, as in the case of some species of *Begonia* and of *Bryophyllum*. In many other plants aerial roots belonging to this class are given off by the stem or branches, which descend to the ground, and, fixing themselves there, not only act as mechanical supports, but assist the true root in obtaining food. Such roots are well seen in the Banyan or Indian Fig-tree (*fig.* 21), and in the Mangrove (*fig.* 22).

FIG. 22.

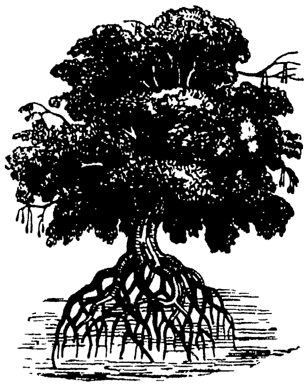


Fig 22 The Mangrove-tree (*Rhizophora Mangle*).

The primary root and its branches constitute what is often called the *root system*. Its form depends upon the relative dimensions of the main root and the branches. When the former persists and is always stronger than its branches, we have the *tap-root* and its modifications. Each branch in such a system is usually stronger than the branches to which it gives rise.

Sometimes the primary root is but slightly developed, and gives off from its sides a multitude of delicate branches which are more or less fibrous. Sometimes again it divides at once into a number of slender branches or rootlets. A root system of this kind is seen in our annual Grasses (*fig.* 30).

The characters of the root system and of the individual roots are always determined by the peculiarities of the lives of the plants to which they belong. Some plants live for a year only, springing from seed, flowering and dying in a single season. These are known as *Annuals*. Their roots are always of small size; they may be either entirely secondary, springing in a tuft from the very short primary one, or there may be a thin tap-root with a number of smaller branches springing from its sides.

Other plants live their lives during two years. In the first they produce leaves and manufacture a considerable quantity of food materials. At the end of the summer this is deposited in the root, which grows to a large size and becomes fleshy and succulent. Such roots are shown by the Radish, Turnip, and Carrot, which are spoken of as *fusiform*, *napiform*, and *conical* respectively (*figs.* 23, 24, 25). In the next year the plant produces its flowers and seeds, using up the stored food supply during the process of growth and flowering. These plants are called *Biennials*.

FIG. 23.

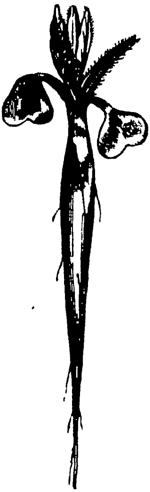


FIG. 24.

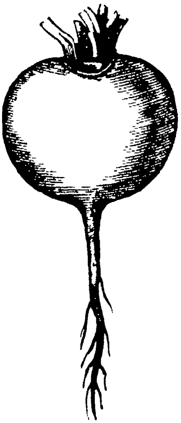


FIG. 25.

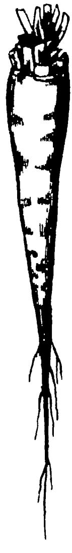


Fig. 23. Fusiform root of the common Radish (*Raphanus sativus*).——*Fig.* 24. Napiform root of the Turnip (*Brassica Rapa*).——*Fig.* 25. Conical root of the Carrot (*Daucus Carota*).

A very large number of plants, as we can easily observe, live for many years. Some of them, however, die down to the ground every winter, the root system being the only part which appears to persist. The roots of these plants also serve as storehouses for food materials which are used in the succeeding spring as the stems reappear and active life is resumed. Such plants are the Dahlia (*fig.* 28), and some Orchids (*figs.* 26 and 27). These *perennial* roots in many cases are woody, like those of plants whose stems also survive the winter. In the case of the Dahlia, we find the roots which store the nutritive material are secondary roots, the primary one not being developed, as is the case in the Grasses. In the Orchis we have a pair of these succulent or *tuberous* roots, one of which perishes every year, while another is developed side by side with the remaining one.

FIG. 26.

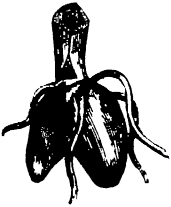


FIG. 27.

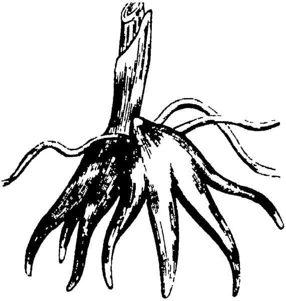


Fig. 26. Tubercular roots of an Orchis.—*Fig.* 27. Palmated tubercular roots of another Orchis.

FIG. 28.

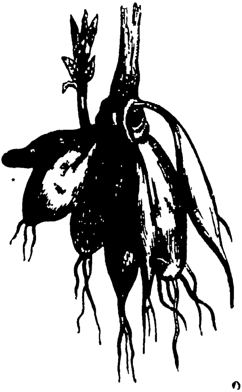


FIG. 29.

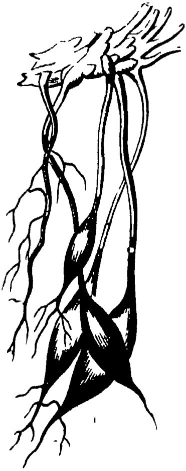


Fig. 28. Fasciculated roots of the Dahlia.—*Fig.* 29. Nodulose root of the common Dropwort (*Spiræa Filipendula*).

The main root in these plants may also be the storehouse of the food material, but it never attains the peculiar development of the root of the biennial plant.

Woody roots are commonly perennial in themselves, and are not renewed.

Certain peculiarities are shown by the roots of plants which do not grow in the soil. Those which are to be met with in water are usually long, unbranched, somewhat fleshy or succulent, and devoid of hairs. They may be denominated *aquatic* roots.

FIG. 30

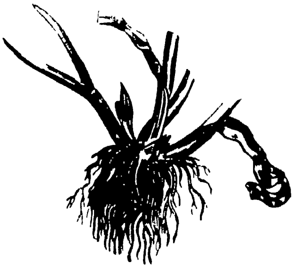


FIG. 31.

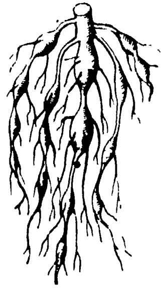


FIG. 32.

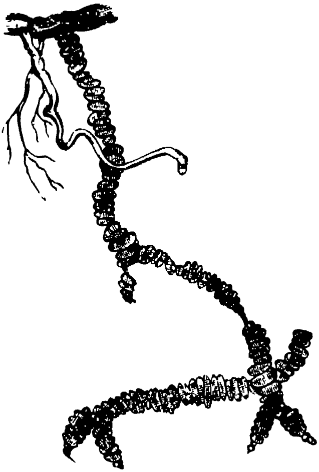


Fig. 30. Fibrous roots of a Grass.——*Fig.* 31. Moniliform or beaded root. ——*Fig.* 32. Annulated root of Ipecacuanha (*Cephaelis Ipecacuanha*).

Two other classes of plants also show modifications which depend upon their peculiar mode of life. These are *epiphytes* and *parasites*.

Roots of Epiphytes or Air-plants.—In many of these plants special aerial roots are produced (*fig.* 33, *a*, *a*), and as these never reach the soil they cannot obtain any food from it, but must draw their food entirely from substances supplied to them by the air in which they are developed; hence the name of *air-*

plants which is applied to them. They are also called *epiphytes*, because they commonly grow upon other plants. They have frequently also small roots of the ordinary type, which penetrate into cracks or crannies in the bark of the supporting plant, enabling them to absorb small quantities of food from the débris which accumulates there. Many of the tropical Orchids (*fig.* 33) afford us illustrations of epiphytic plants. The aerial roots of such plants are frequently green and serve as organs for constructing food. The aerial roots of Orchids have a layer of usually very delicate fibrous cells covering them, which assists in the absorption of moisture from the air.

Roots of Parasites.—These are plants which not only grow upon others, but which, instead of sending roots into the air and deriving food-material from it, as do the epiphytes, insert peculiar root-like bodies into the tissues of the plants upon which they grow, and obtain nutriment from them. The plant which they thus penetrate and feed upon is termed their *host*; and the sucking roots are called *haustoria*. They differ from true roots in the manner of their origination, as we shall see later. The Mistletoe (*Viscum album*), Broom-rapes (*Orobanche*), Dodders (*Cuscuta*) (*fig.* 34), and *Rafflesia Arnoldi* (*fig.* 35) may be cited as examples of such plants. These parasites differ from each other in appearance; some have green foliage, as the Mistletoe; while many others are pale or brownish or possess other tints than green, as the Broom-rapes and *Rafflesia*.

Parasitic plants vary in the degree of their parasitism;

FIG. 33.

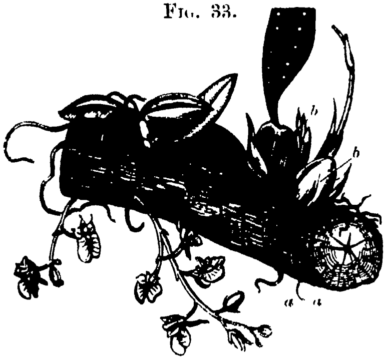


Fig. 33. Epiphytic orchidaceous plants, showing their mode of growth. *a*, *a*. Aerial roots. *b*, *b*. Pseudobulbs.

the Mistletoe and the greater number of parasites are, so far as their roots are concerned, entirely dependent upon the plants on which they grow for their food. Others obtain food-material at first, like other plants, by means of ordinary roots contained in the soil; but after having arrived at a certain age these perish, and they then derive their food entirely through haustoria which penetrate the plants upon which they grow. Others, again, continue throughout their life to obtain a portion of their food-material by means of roots embedded in the soil while they possess in addition haustoria which are inserted into the roots of plants growing side by side with them. These are often called *root-parasites*; besides taking in nutritive material from the soil and from their host plants, they absorb certain constituent elements of their food from the air by their green leaves.

FIG. 34.

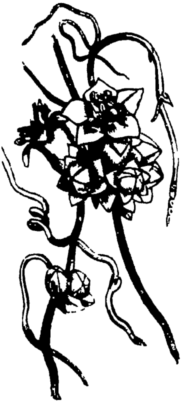


FIG. 35.

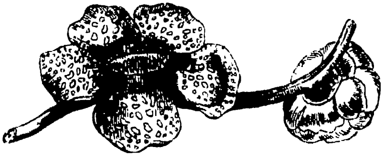


Fig. 34. Cuscuta or Dodder-plant. — *Fig.* 35. Flower and flower-bud of *Rafflesia Arnoldi*, a parasitic plant of Sumatra.

It will thus be seen that parasites differ from other plants in that they are not entirely dependent for the raw materials of their food upon the soil and the air, but that they derive at least some of it in an assimilable state from the plants on which they grow. Those which are green, like the Mistletoe, obtain certain constituents of their food, like ordinary plants, from the air; those which have no green colouring matter derive all their nourishment by their roots from the plants on which they live. It consequently happens that parasites, by living partially or entirely upon those plants on which they are placed, frequently injure and even destroy them, and in this way great damage is done to Clover, Flax, and other crops in this country and elsewhere.

Besides the parasites just described, there is also another class of plants called *saprophytes*, which, whilst agreeing with parasites in deriving their food from already formed organic material, differ from this latter class by growing on dead organic substances, and therefore assimilating such matter as is in a state of decomposition or decay. Such plants as *Monotropa Hypopithys*, *Corallorhiza innata*, *Epipogium Gmelini*, and *Neottia Nidus-avis*, together with the greater number of Fungi, are examples of Saprophytes.

In the plants which are lower in the scale than the Vascular Cryptogams, the roots are generally of a very simple type. In all of them the root may be described as the descending axis of the plant, as its growth is always in the opposite direction to that of the shoot. It may be extremely rudimentary, as in some of the lowest of the Algæ or Seaweeds, where it consists only of a single terminal cell, which soon perishes. It may be formed of a mass of cells, sometimes tapering and branched, and hardly distinguishable from the thalloid shoot to which it is attached; or it may be a long hair-like structure, much resembling the root-hairs described as arising on the roots of the sporophyte of the higher forms. In these lowly forms the root is only recognisable in the gametophyte. The sporophyte is never so far differentiated as to possess one.

There are not wanting instances again of plants which bear no primary root at all. Such are the gametophytes of the Liverworts, the sporophytes of *Salvinia* and *Psilotum* among the Pteridophyta, and of *Utricularia*, *Epipogium*, and *Corallorhiza* among flowering plants. The functions of the root are in these cases discharged by modifications of other members of the plant body, or by adventitious roots developed after the stem and leaves have been differentiated.

SECTION II.—THE SHOOT.

A. The Stem.

The stem is that part of the axis which at its first development in the embryo takes an opposite direction to the root; it is termed the ascending axis, and bears on its surface the leaves and other leafy appendages (*fig.* 36, *t*). It usually grows vertically into the air, though this is not invariable; sometimes it is slender and weak, and trails along the ground; sometimes it buries itself beneath the surface and in general appearance resembles the root, from which, however, it can be distinguished by bearing leaves. The presence of leaves is therefore the essential characteristic of a stem, in contradistinction to a root, from which such structures are normally absent.

The appendages of the stem arise in acropetal succession, as do those of the root; but, unlike the latter, their places of origin are very definite. We can distinguish on a stem the points from which they arise, which are known as *nodes* (*fig.* 38 *c,c,c*). Each node may produce one leaf or more, and in the *axils* of the foliage leaves, or the angle formed between the stem and leaf, a branch or branches may arise. The branch in many cases is not developed far, though it is always indicated. The spaces between the nodes, which are always naked, are called *internodes* (*fig.* 38, *d*, *d*). The difference in appearance between the nodes and internodes is most evident in those cases where the internodes are clearly developed, especially if under such circumstances the leaf or leaves which arise encircle the stem, as in the Bamboo and other Grasses. In such plants each node exhibits the formation of a hardened ring bulging externally, and thus produces the appearance of a joint or articulation. In some cases, the stem easily separates into distinct portions at these joints, as in the common Pink, the stem then being said to be *jointed* or *articulated*.

Fig. 36.

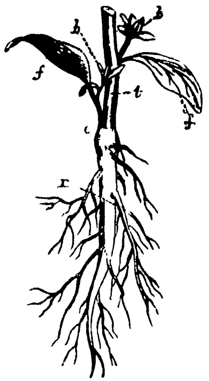


Fig. 36. Lower part of the stem and root of the common Stock. *r*. The root with its branches. *t*. The stem. *f*, *f*. Leaves. *b*, *b*. Leaf-buds.

At the apex of the main stem and of all its branches we find the surface covered by the young leaves, which, growing faster than the stem itself, roof it over and protect it. The apex of the stem is never covered by a cap like that of the root. The growth of the stem in length is confined to the young internodes, and at first these remain short, the nodes being compressed together. The leaves at first grow most strongly on their lower sides, and are thus enabled to arch over the stem. During the period of active growth of the stem the young leaves are very loosely arranged, but when, as in the winter, such growth is suspended many of them are closely crowded together. The resting apex with its covering of leaves is then known as the *bud*. It is usual to speak of *terminal* and *lateral* buds, according to their position at the apex of the main stem or in the axils of the leaves. In the latter case, however, the buds are the terminations of the branches and are therefore really terminal.

The buds of temperate and cold climates, which remain dormant during the winter, and which are accordingly exposed to all its rigours, have generally certain protective organs developed on their outer surface in the form of modified leaves which are commonly called *scales*, or *cataphyllary* leaves. These are usually of a hardened texture, and are sometimes covered with a resinous secretion, as in the Horse-chestnut and several species of Poplars; or with a dense coating of soft hairs or down, as in some Willows. Such scales, therefore, by interposing between the tender rudimentary leaves of the bud and the air a thick coating of matter which is a bad conductor of heat, protect them from the influence of external conditions, by which they would otherwise be injured, or even destroyed. Buds thus protected are sometimes termed *scaly*. In the buds of tropical regions, and those of herbaceous plants growing in temperate climates which are not thus exposed to the

FIG. 37. FIG. 38. FIG. 39.

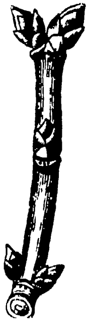


Fig. 37. A shoot one year old of the Horse-chestnut, with terminal bud *a*. Scar produced by the falling off of the bud-scales of the previous year. *b*. *b*. Scars caused by the falling off of the petioles of the leaves of the present year, with buds, *c*, in their axils.—— *Fig.* 38. Diagram to illustrate the growth of the shoot from the bud. *c*, *c*, *c*. The nodes where the leaves are situated. *d*, *d*. The internodes developed between them.—— *Fig.* 39. Shoot of the Lilac (*Syringa vulgaris*), showing suppression of the terminal bud, and two lateral buds in its place (*false dichotomy*).

influence of a winter, such protective organs would be unnecessary, and are accordingly absent, and hence all the leaves of these buds are of nearly the same character. Such buds are called *naked.* In a few instances we find that the buds of perennial plants growing in cold climates, which are exposed during the winter, are naked like those of tropical and herbaceous plants. Such is the case, for instance, with the Alder Buckthorn (*Rhamnus Frangula*), and those of some species of *Viburnum.*

These protective organs of the bud are commonly, as we

FIG. 40.

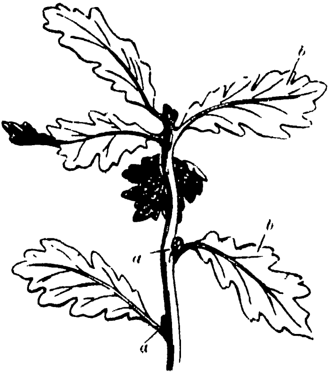


FIG. 41.

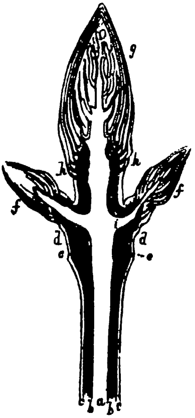


Fig. 40. Branch of Oak with alternate leaves and leaf-buds in their axils. *a*, *a*. Buds. *b*, *b*. Leaves.——*Fig.* 41. Vertical section through the end of a twig of the Horse-chestnut (*Æsculus Hippocastanum*), before the bursting of the bud. After Schleiden.

have just mentioned, termed *scales*, but they have also received the name of *tegmenta.* That such scales are really only modified leaves adapted for a special purpose, is proved not only by their position with regard to the true leaves, but also from the gradual transition, which may be frequently traced from them to the ordinary leaves of the bud. These scales have only a temporary duration, falling off as soon as the growth of the bud commences in the spring.

The bud thus contains all the elements of a stem or branch; as we have seen, it is really the first stage in the development of these parts, the axis being here so short that the rudimentary leaves are closely packed together, and thus overlap one another. When growth commences in the spring, or whenever vegetation is reanimated, the internodes between the leaves become developed (*fig.* 38, *d, d*), and these therefore become separated from one another, *c, c, c*, and thus the stem or branch increases in length, or a new branch is formed. In other words, the leaves which in a bud state overlap one another and surround a growing point or axis, by the elongation of the internodes of that axis become separated and dispersed over a branch or an elongation of the stem.

It frequently happens that many of the lateral buds never develop into branches. This is generally the case with those which are produced in the axils of the lower leaves of the twigs of most trees. Sometimes, though not developed at once, they retain for years the power of growing into branches. These buds are called *dormant* buds, and the branches ultimately arising from them are known as *deferred* branches. When they appear, they seem to be developed out of their proper places, and make the branching appear very complicated.

BRANCHING.—Just as branches are produced on the main axis or stem, so from the axils of the leaves of these branches other buds and branches are formed; these again will form a third series, to which will succeed a fourth, fifth, and so on. When a branch system is well developed in this way, the term *branch* is often applied to the larger divisions only, the smaller being known as *twigs*. The large branches of trees are generally called *boughs*. The general arrangements of the divisions of the stem constitute its *branching*, which may be defined as the lateral development of *similar parts*. The divisions of a stem or root are branches; but the lateral development from a stem or branch, of leaves or other *dissimilar* parts such as hairs, is not branching.

There are two principal types of branching, the *lateral* and the *dichotomous*. When the axis continues to develop in an upward direction by a terminal bud or growing point, and its branches are produced from smaller growing points originating laterally on the main one, the branching is called *lateral*. This is, probably, the universal system of branching in Angiosperms, although there are some apparent exceptions. But when the terminal bud or growing point *bifurcates*, and thus produces two shoots, which, at any rate at first, are of equal strength, so that the foot or *podium* bears two branches arranged in a forked manner (*fig.* 42), the branching is termed *dichotomous*. This form is common in many of the Cryptogams.

In dichotomous branching we have again two forms: one which is termed *true* or *normal dichotomy*, in which the two branches continue to develop equally in a forked manner—that is, each becomes the podium of a new dichotomy (*fig.* 42)—and a second, in which at each division one branch grows much more vigorously than the other and divides into two, while the other remains undivided; this is called *sympodial* (*fig.* 43, A and B). In this latter case, owing to the unequal growth of the branches, the strong limbs of successive bifurcations form together an axis which is termed the *pseud-axis* or *sympodium*, from which the weaker fork-branches or bifurcations appear to spring as lateral branches (*fig.* 43, A, *r*, *r*, *r*, *r*, and B, *r*, *l*, *r*, *l*, *r*). This branching might at first sight be confounded with the monopodial type of lateral branching, in which we have a continuous axis giving off lateral branches; but it differs in the fact that here the apparent primary axis consists of a succession of daughter-axes fused together in the course of development.

FIG. 42.

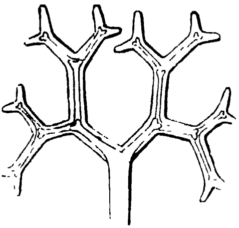


FIG. 43.

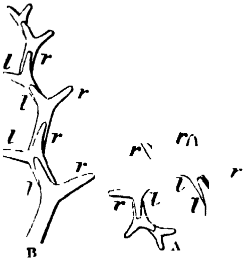


Fig. 42. Diagram of normal or true dichotomous branching, showing the two branches equally developed in a forked manner, and each branch dividing in succession in a similar way.——*Fig.* 43. Diagrams of sympodial dichotomous branching. A. Helicoid dichotomy. B. Scorpioid dichotomy. In A, the left-hand branches, *l*, *l*, *l*, of successive dichotomies are much more developed than the right, *r*, *r*, *r*, *r*. In B, the left-hand branches, *l*, *l*, and those of the right hand, *r*, *r*, are alternately more vigorous in their growth. The limbs of the dichotomy which become the successive segments of the sympodium are indicated by the lines drawn inside the latter. After Sachs

In sympodial branching, the sympodium may be either formed of the fork-branches of the same side (left or right) of successive dichotomies (*fig.* 43, A, *l*, *l*, *l*); or it may consist alternately of the left and right fork-branches or bifurcations (*fig.* 43, B, *l, r, l, r*). In the former case it is called *helicoid dichotomy*; in the latter, *scorpioid dichotomy.*

Of the lateral branching there are also two forms, the *racemose* or *monopodial* and the *cymose*. In the first the primary axis continues to develop upwards and gives off acropetally lateral branches from axillary buds, which also give off lateral branches in a similar manner. The main axis here constitutes a *monopodium*, as it forms a single foot or podium for the branches. In the cymose form the lateral axes at an early age develop much more vigorously than the primary axis, and each gives rise to other lateral branches in a similar way (*fig.* 44, A). In some plants an apparent but false dichotomy is produced by the partial or total suppression of the terminal bud or main growing point and the subsequent vigorous growth of the closely arranged lateral buds, which so form two shoots apparently radiating from a common point, as if caused by the division of the terminal bud, as in true dichotomous branching.

FIG. 44.

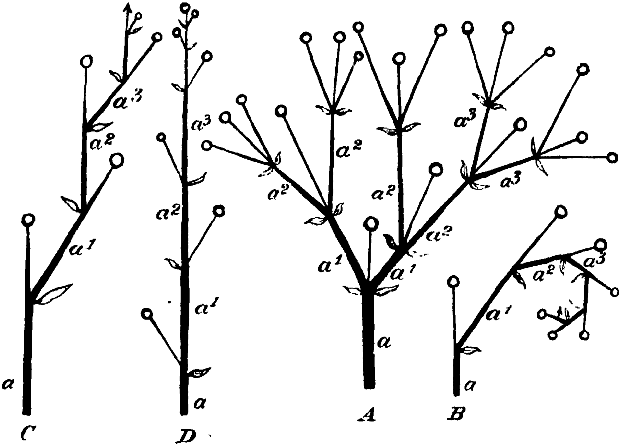


Fig. 44. Diagram to illustrate cymose branching. A. Dichasial cyme or Dichasium. The successive axes are marked by the letters, a, a^1, a^2, a^3. The continuation of each axis above the point of origin of the axes springing from it is the thin line terminated by a small circle. B. Dichasium with the successive axes suppressed on one side, forming a helicoid sympodium. C. Scorpioid sympodium formed by the suppression of the successive axes on alternate sides. D. The same after it has become straightened by growth. The apparent monopodium is seen to be composed of parts of the successive axes.

This suppression of the terminal bud may occur naturally, as in the Lilac (*fig.* 39), or accidentally from frost or other injury.

When two buds arise just behind the apex and two branches are consequently developed there, as in *fig.* 44, A, the branch system is called a *dichasium*; when there are more than two a *polychasium* results. The branch system in these cases may be called *polypodial.* When, on the other hand, only one branch is developed at each point, and this becomes stronger than the one from which it springs, we have a pseud-axis or *sympodium* formed, closely resembling the sympodium of dichotomous branching. It can be distinguished from the latter by the fact of the branch arising behind the original growing point, and not from its division. The sympodium may be helicoid or scorpioid as in the other case. The branching of many forest trees is of this kind.

The pseud-axis as first formed is crooked, and shows its mode of formation (*fig.* 44, B, C). As it gets older the continued growth and thickening of its successive parts cause it to become straight (*fig.* 44, D), and it is then very difficult to distinguish it from a monopodium, particularly when the leaves have fallen off.

These modes of branching will be again alluded to under the head of INFLORESCENCE, or the arrangement of the flowers, in which connection they will be more fully illustrated.

All lateral or axillary buds are called *regular* or *normal,* and their arrangement in such cases is necessarily the same as that of the leaves. As branches are formed from buds thus placed, it should follow that their arrangement should also correspond to that of the leaves. This corresponding symmetry, however, between the arrangement of the branches and that of the leaves is interfered with from various causes. In the first place, many of the regular buds may not be developed. Secondly, other buds may arise irregularly at various other points than the axils of leaves: these are called, from their abnormal origin, *adventitious.* And, thirdly, *accessory* buds may be formed.

1. *Non-development of the Regular Buds.*—This frequently takes place irregularly, and is then owing altogether to local or special causes; want of light, too much crowding, or bad soil may cause many buds to become abortive, or to perish after having acquired a slight development. In other cases, however, this non-development of the buds takes place in the most regular manner; in Firs, for example, where the leaves are very closely arranged in a spiral manner, the branches, instead of presenting a similar arrangement, are placed in circles around the

axis at distant intervals. This arises from the non-development of the buds of many of the leaves which form the spire, which is followed by the development of those of closely succeeding leaves; and as such leaves are thickly placed, we are unable, after the development of the branches, to trace clearly the turns of the spire, so that the branches appear to be arranged in a circle.

2. *Adventitious Buds.*—These have been found on various parts of the plant, such as the root, the woody portion of the stem, the leaves, and other organs. When a tree is *pollarded*—that is, when the main branches and the apex of the trunk are cut off, and a great quantity of nutritive material subsequently accumulates in the latter—a multitude of adventitious buds are formed, from which branches are developed. The branches thus produced by pollarding are, however, often supplemented by the development of regular buds which have become dormant from some cause having at first interfered with their growth.

FIG. 45.

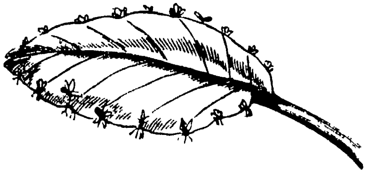


FIG. 46.

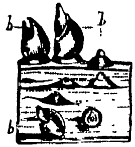


Fig. 45. Leaf of *Bryophyllum calycinum* with buds on its margins.—*Fig.* 46. A portion of the leaf of *Ornithogalum thyrsoideum*, showing buds, *b*, *b*, *b*, on its surface.

We have seen that normally leaves do not give rise to other leaves or to branches. Occasionally, in consequence of wounds, the latter do arise, and, indeed, are often produced artificially, on various leaves, such as those of species of *Gesnera*, *Gloxinia*, and *Begonia*. They are cut in various places and subsequently placed in a moist soil, and exposed to the other influences which are favourable for the growth of buds. The branches developed on the leaves, in such cases, ultimately form independent plants, and this process is therefore constantly resorted to by gardeners as a means of propagation. These adventitious branches differ from those commonly produced in the axils of leaves, or at least from those which remain dormant during the winter, in being smaller, and having no external protective organs or scales (*figs.* 45–46).

3. *Accessory Buds.*—The third cause of irregularity in the distribution and appearance of branches arises from the multiplication of buds in the axils of leaves. Instead of one bud, we have in rare cases two, three, or more, thus situated (*figs.* 47-49); such are called *accessory buds.* These buds may be placed either one above another or side by side. In certain Willows, Poplars, and Maples, we have three buds placed side by side (*fig.* 47, *a*), which frequently give rise to a corresponding number of branches. In some Aristolochias, in Walnuts (*fig.* 48, *b*), in the Tartarian Honeysuckle (*fig.* 49, *b*), and other plants, the accessory buds are arranged one above another.

FIG. 47.

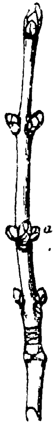


FIG. 48.

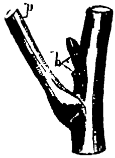


FIG. 49.

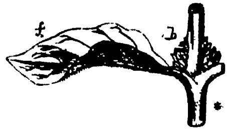


Fig. 47. Branch of a species of Maple with three buds, *a*, placed side by side.—*Fig.* 48. A piece of a branch of the Walnut-tree. *p*. The petiole having in its axil a number of buds placed one above the other, the uppermost, *b*, most developed.—*Fig.* 49. A piece of a branch of the Tartarian Honeysuckle (*Lonicera tartarica*), bearing a leaf, *f*, with numerous buds, *b*, in its axil, placed above one another, the lowermost being the most developed.

Sometimes the uppermost bud alone develops (*fig.* 48, *b*), as in the Walnut, and so the branch which is formed arises at a point on the stem higher than the axil of the leaf, and appears as if it were on the internode. It is not really so, as the node is longer than a normal node. The leaf is then said to be *extra-axillary*. In the Tartarian Honeysuckle (*fig.* 49, *b*), the axillary or lowest bud is that which forms the strongest branch, over which a number of smaller branches are placed, arising from the development of the accessory buds. In some trees, as the Larch and Ash, and frequently in herbaceous plants, such as the Asparagus, the branches which are formed from the accessory buds, which are often very numerous, instead of remaining separate, fuse together laterally as they grow, and develop as a broad, flat, and apparently single branch. Such abnormal branches are commonly called *fasciated*. Fasciated branches may, however, be produced by a single bud developing in an irregular manner.

In some cases, as in *Cuscuta*, several buds occur in the axil of the same leaf, owing to the branching of the original single one.

Besides the three principal cases mentioned of abnormal or irregular development of the branches, some minor ones are met with arising from the formation of *extra-axillary* branches in other ways than those just alluded to. The branch may adhere for a short distance either to the stem or to the leaf-stalk, causing curious apparent displacements.

Sometimes the subtending leaf is suppressed, as in many inflorescences, where the flower seems to spring from the stem quite independently. In some Mosses the normal position of the branch is at the back of the leaf instead of in its axil; in others it arises at the side of the leaf. These variations follow the mode of division of the cell from which both leaf and branch originate. In some of the higher plants, both in the Vascular Cryptogams and the Flowering Plants, each branch appears by the side of a leaf. In others there is no relation at all between the origins of the two members, as in *Lycopodium*. Floral and scaly leaves, moreover, do not bear branches in their axils.

Adventitious shoots sometimes arise from roots, as may be observed in many *Rosaceæ*, the Moutan Pæony, the Japan Anemone, and many other plants. They may in many cases be artificially stimulated to appear; if the root be wounded, it will often produce them, much in the same way as do the leaves of *Begonia*. The Blackberry under such circumstances will produce shoots from its roots, so freely indeed that the plant can be propagated by root-cuttings.

FORMS OF STEM AND BRANCHES.—The stem is usually more or less cylindrical, though this is far from universal. In many herbaceous plants it becomes angular, and in some, particularly in those of certain natural orders, as the *Cactaceæ*, *Orchidaceæ*, *Euphorbiaceæ*, &c., it assumes a variety of anomalous forms. In many epiphytic Orchids it becomes more or less oval or rounded, and has received the name of *pseudo-bulb* (*fig.* 33, *b*, *b*); in the Melon-cactus it is globular; and in other Cacti it is columnar, more or less flattened, or jointed. In the Tortoise or Elephant's-foot Plant (*Testudinaria elephantipes*), it forms a large rough irregular mass.

In general, stems are strong and rigid, and can therefore readily sustain themselves in an upright position; but many are too weak to support themselves; these either trail along the ground, or attach themselves to some other plant or neighbouring object. Those which trail on the ground are said to be *procumbent* or *prostrate*; if when thus reclining they rise towards their extremity, they are *decumbent*; if they rise obliquely from near the base, *ascending*. Those which cling to neighbouring plants or other objects for support are called *climbing* if they proceed in a more or less rectilinear direction, as in the Passion-flower, where they adhere to other bodies by means of little twisted ramifications called tendrils, or in the Ivy, where they emit little aerial roots from their sides, by which they cling to neighbouring bodies (*fig.* 50, *a*, *a*). If such stems twist round other bodies in a spiral manner, they are said to be *twining*; and this twining may take place either from right to left, as in some Convolvuli (*fig.* 52), French Bean, and Dodder;

FIG. 50.

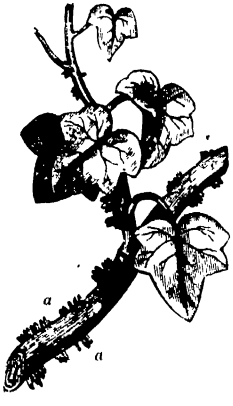


Fig. 50. Climbing stem of the Ivy. *a*, *a*. Aerial roots.

FIG. 51.

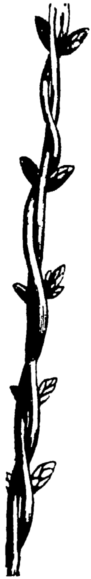


Fig. 51. Twining stem of Honeysuckle.

FIG. 52.

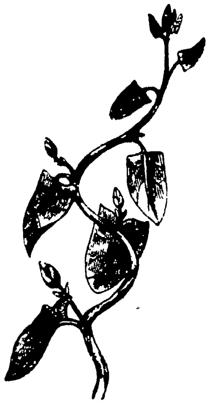


Fig. 52. Twining stem of a species of *Convolvulus*.

or from left to right, as in the Honeysuckle (*fig.* 51 Hop, and Black Bryony; or first in one direction and then in another, irregularly, as in the White Bryony. The climbing and twining stems of cold and temperate regions are generally herbaceous or die annually, although we have exceptions in those of the Ivy, Clematis, and Honeysuckle, which are woody. In tropical climates these woody climbing and twining stems often occur; they are called *lianas* or *lianes*, and they frequently ascend to the tops of the loftiest trees, and then either descend to the ground again, or pass to the branches of neighbouring trees.

The stem has received many names according to its nature. It is called a *caulis* in plants which are herbaceous, or die down annually to the surface of the ground; a *trunk*, in trees, where it is woody and perennial; a *culm*, in most Grasses and Sedges, where it presents a jointed appearance; and a *caudex* or *stipe*, in Tree-ferns and Palms.

Herbs, Shrubs, and Trees.—From the nature, duration, and mode of branching of stems, plants have been arranged from the earliest periods in three divisions, called, respectively, *Herbs*, *Shrubs*, and *Trees*. Those plants which have stems that die down annually to the surface of the ground are called *herbs*; while those with perennial aerial woody stems are denominated *trees* or *shrubs* according to circumstances, as described below. Herbs are also further characterised as *annual*, *biennial*, and *perennial*. They are *annual* when they live only through one season, that is, between the spring and winter; *biennial*, when they spring from seed in one season, and die in the second, after producing flowers, fruit, and seed; and *perennial*, when they spring from seed in one season, and continue to live through a succession of years, the sub-aerial parts dying down in the autumn, and in the succeeding spring new herbaceous stems growing up. The term *tree* is applied if the branches are perennial and arise from a trunk. When the branches are perennial and proceed directly from, or near to, the surface of the ground, without any trunk, or where this is very short, a *shrub* is formed; this, when low and branched very much at the base, is denominated a *bush*. The term *undershrub* is applied to a small shrub which is intermediate in its characters between an ordinary shrub and an herb; in such a plant some of its branches generally perish annually, while others are more or less permanent. All these kinds of stems are connected by intermediate links, so that in many cases they are by no means well defined.

The shape of a tree is very largely dependent upon its method of branching. When the latter is distinctly and continuously racemose, the axis being prolonged upwards in a straight line from base to summit and the lateral branches growing acropetally from its sides and branching similarly themselves, we have trees of pyramidal form, as most Firs. When, on the other hand, the branching is cymose, the head of the tree becomes more or less rounded, as we see in many of our forest trees. In the case of racemose branching, the stem is technically said to be *excurrent*; in that of cymose branching, *deliquescent*.

The shape of a tree depends not only on the character of the branching, but on the nature of the branches and the angle they make with the stem from which they arise. We see illustrations of this if we compare the Cypress and the Cedar, the Oak and the Lombardy Poplar. A very peculiar form is met with when the angle of the branches is very obtuse, and the latter bend downwards from their origin, as in the Weeping Ash and Weeping Elm. A similar appearance is presented by the Weeping Willow and the Weeping Birch, but in these cases the drooping of the branches is due to their weakness and flexibility.

In many of the trees with excurrent stems the lower branches perish comparatively early, instead of growing out to great length. The tree, instead of being pyramidal in form, then has a naked trunk of some length, as may be seen in many fir trees.

KINDS OF STEM AND BRANCHES.—We have seen that the stem when first developed always grows upwards, while the root at the same time grows downwards. In many instances this original direction of the stem is continued more or less throughout its life, but there are many cases in which, for various reasons connected with the habit of life of different plants, this does not take place, the stem being curiously modified to serve different purposes. Sometimes it or some of its branches remain underground, and look very much like roots, from which, however, they can be distinguished by bearing leaves. From these peculiarities in the direction and growth of stems and branches, we have a number of modifications needing description. These are best treated of under two heads, namely, those which are *aerial*, and those which are *subterranean*. We can, however, by no means draw a distinct line between the modifications of stem which these two divisions respectively contain, as certain forms occasionally pass from one into the other, being subterranean and aerial at different points, or at different periods of their course.

1. **Aerial Modifications of the Stem and Branches.**—Of these the more important are the *runner*, the *offset*, the *stolon*, the *sucker*, some forms of the *rhizome*, the *phylloclade*, and the *thorn*. Certain forms of *tendril* may be included here. The *flower* is also a modified shoot. The rhizome is usually subterranean, and will be described later.

Fig. 53.

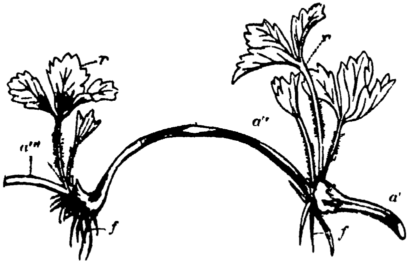
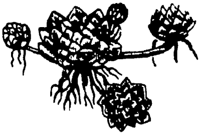


Fig. 55.

Fig. 54.



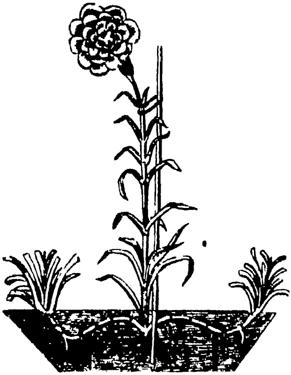


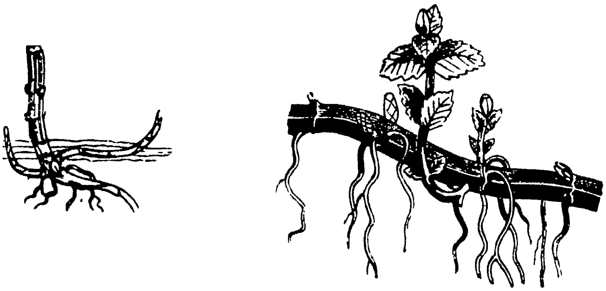
Fig. 53. A portion of the common Strawberry plant. a'. An axis producing a tuft of leaves at its extremity, the upper of which, r, are well-developed and green, and the lower rudimentary. From the axil of one of the latter a second axis or runner, a'', arises, bearing a rudimentary leaf, f', near the middle, and a cluster of leaves, r, at its end. a'''. A third axis produced in a similar manner to the former. f, f. Roots or rootlets.——*Fig.* 54. Offset of *Sempervivum*.——*Fig.* 55. Plant showing the process of *layering*.

a. *The Runner or Flagellum* (*fig.* 53).—This is an elongated, slender, prostrate branch, a', sent off from the base of the stem and giving off at its extremity leaves, r, and roots, f, and thus producing a new plant, which extends itself in a similar manner. The common Strawberry propagates itself in this fashion.

b. *The Offset* (*fig.* 54).—This is a short, prostrate, more or less thickened branch, which produces at its apex small roots and a tuft of leaves, and thus forms an independent plant, which is capable of producing other offsets in a like manner. It is well seen in the Houseleek. It differs very little from the ordinary runner, except in being shorter, somewhat thicker, and having its leaves distinctly tufted.

c. *The Stolon.* This is a branch which is given off above the surface of the earth, but which curves downwards towards it; when it reaches a moist spot it sends rootlets into the ground, and a stem upwards into the air; being thus capable of acquiring food independently of its parent, it ultimately forms a new individual. The Currant, Gooseberry, and other plants, multiply in this way. All such plants are said to be *stoloniferous*. Gardeners imitate this natural formation of new individuals when they press down a branch into the earth, a new plant being ultimately formed from it; this process is technically called *layering* (*fig.* 55).

FIG. 56. FIG. 57.



Figs. 56 and 57. Suckers of species of *Mentha.*

d. *The Sucker* (*figs.* 56 and 57).—This is a branch which arises from the stem below the surface of the earth, and which, after proceeding in a horizontal direction for a certain distance, and giving off little roots or rootlets in its course, turns upwards into the air, and ultimately forms an independent plant. Good examples of this kind of stem are seen in the Rose, the Raspberry, and the Mint. The sucker can scarcely be said to differ in any essential particulars from the stolon, except that it is originally subterranean and ultimately aerial; whereas the stolon is first aerial, and then subterranean.

e. *The Phylloclade.*—In some plants the leaves are very feebly developed and soon fall off, or are modified into spinous or needle-like processes. In such cases the stem performs the functions of the leaves, becoming green and assuming a flattened or rounded form. Such a stem is called a *phylloclade.* Examples may be seen in many Cactuses, where the stem is either globular, or composed of flattened or round joints, or of winged columns. In certain *Liliaceæ* the phylloclade has the shape of an ordinary foliage leaf, from which it can be distinguished by bearing leaves and flowers, either on its margins or at some point on its surface. Such a branch consists of only one internode; it is soft and pointless in *Myrsiphyllum*; firm, hard, and spiny at its apex in *Ruscus aculeatus* (*fig.* 58). Its stem-character can be seen also from its arising from the axil of the true leaf, which is very small and soon falls off. Phylloclades of this kind have also been called *cladodes.*

FIG. 58.

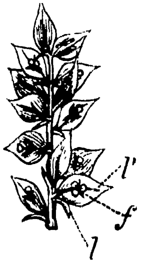


FIG. 59.

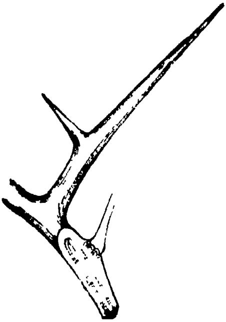


FIG. 60.

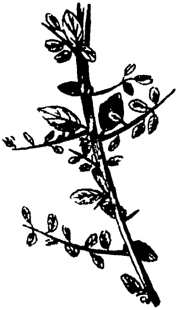


Fig. 58. Phylloclade of *Ruscus aculeatus.* *l*, leaf; *p*, phylloclade; *f*, flower. *Fig* 59. Branching thorn of the Honey Locust (*Gleditschia*).——*Fig* 60. Leafy thorns of the common Sloe.

f. *The Thorn.*—It sometimes happens that a normal bud, instead of developing as usual, and producing a symmetrical leaf-bearing branch, becomes arrested in its growth, and forms a hardened simple or branched projection terminating in a more or less acute point, and usually bearing no leaves, as in *Cratægus*, *Gleditschia* (*fig.* 59), and many other plants. Such an irregularly developed branch is called a *thorn*. That the thorns are really modified branches is proved not only by their structure, which is exactly the same as the stem or branch upon which they are placed, but also by their position in the axils of leaves; by their sometimes bearing leaves, as in the Sloe (*fig.* 60) and Spiny Rest-harrow; and by their being frequently changed into ordinary leaf-bearing branches by cultivation, as in the Apple and Pear. Thorns are sometimes confounded with prickles, but they are readily distinguished from these by their structure and connection with the internal parts of the stem; the prickles being merely formed of hardened parenchyma,

FIG. 61.

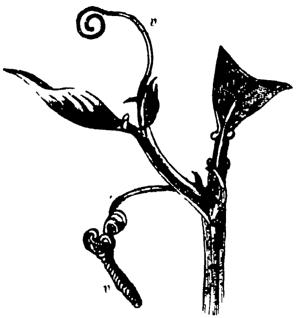


FIG. 62.

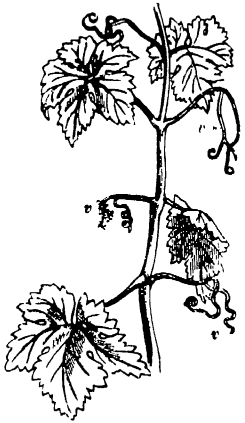


Fig. 61. A portion of the stem of *Passiflora quadrangularis*. *v v* Tendrils. *Fig.* 62. Part of the stem of the Vine. *v v*, *v* Tendrils.

arising immediately from, and in connection only with, the epidermal tissue and cortical cells beneath. Thorns must not be confused with *spines*, which are prickly bodies arising generally upon the margins or apices of leaves, as in the Holly. Sometimes a whole leaf is metamorphosed into such a spine. Both these modifications serve as means of defence of the plant against the attacks of browsing animals.

g. *The Tendril.*—Another irregularly developed branch is the *tendril* or *cirrhus*: this term is applied to a thread-like leafless branch, which twines itself spirally round some supporting body, as in the Passion-flower (*fig.* 61, *v*, *v*). Its peculiar characteristic is that it is sensitive to contact with a foreign body, such as a stick or similar object, and when thus excited it coils round it. Tendrils may be also observed in the Vine (*fig.* 62, *v, v, v*), where they are the terminations of separate axes.

Tendrils are occasionally produced from leaves and some other organs of the plant; these peculiarities will be referred to hereafter, in the description of those organs of which they are respectively modifications.

2. SUBTERRANEAN MODIFICATIONS OF THE STEM AND BRANCHES. All these modifications of the stem and branches were formerly confounded with roots. They are distinguished, however, from roots, either by the presence of buds or of scales (*cataphyllary leaves*), or by the presence of scars on their surface which are produced by the falling off of former leaves or buds. The different kinds of aerial stems described above, when partially subterranean, may be also distinguished in a similar manner from roots.

FIG. 63.

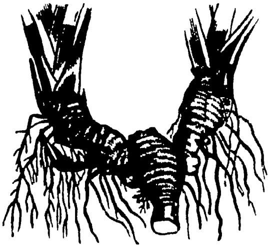


FIG. 64.

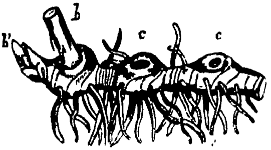


Fig 63. A portion of the rhizome of a species of *Iris*.——*Fig.* 64. A portion of the rhizome of the Solomon's Seal (*Polygonatum multiflorum*) *b*. Remains of the flowering stem of the present year. *b'*. Lateral bud, which will produce the flowering stem of the next year. *c, c*. Scars produced by the decay of the flowering stems of the two preceding years. *r, r*. Rootlets The whole rhizome is a sympodium.

a. *The Rhizome or rootstock* (*figs.* 63, 64, and 65).—This is a prostrate thickened stem or branch running along the surface of the ground, or more generally partly or entirely beneath it, and giving off small roots or rootlets from its lower, and leaves and buds from its upper side. These stems sometimes creep for a long distance in this way, and have their upper surface then marked by scars (*fig.* 64, *c,c*), which mark the limits of the successive annual growths or aerial shoots. Such stems are found in the Iris, Sweet-flag, Ginger, Turmeric, Solomon's Seal, Fern, and many other plants. In some cases these rhizomes are placed in a vertical direction in the earth (*erect rhizomes*), and they then bear a great resemblance to roots, as in the Devil's-bit Scabious (*Scabiosa succisa*), where such a rhizome is commonly but erroneously known as a *præmorse root* (*fig.* 66).

The rhizome may continue to elongate at its apex throughout its life as in the Bracken Fern, or the apex may grow out into an aerial shoot, while a bud is formed laterally in the axil of a leaf at its base. This continues the elongation of the rhizome, causing the formation of a sympodium, as in Solomon's Seal (*fig.* 64).

Fig. 65.

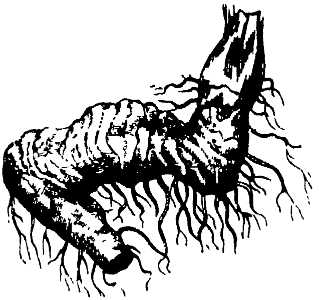


Fig. 66.

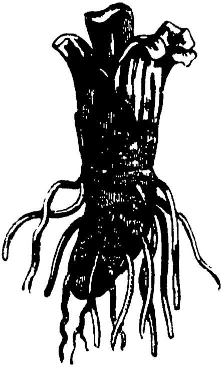


Fig. 65. Contorted rhizome of Bistort (*Polygonum Bistorta*). *Fig.* 66. Præmorse rhizome of the Devil's-bit Scabious (*Scabiosa succisa*)

b. *The Creeping Stem* (*fig.* 67). This kind of stem is a slender branch which runs along beneath the surface of the earth, emitting small roots from its lower side, and buds from its upper, in the same manner as the rhizome, and it is considered by many botanists as a variety of that stem. The only differences existing between the creeping stem as defined above and the rhizome are its more slender form, its commonly greater length, and its entirely subterranean course. The Sand Sedge (*Carex arenaria*) (*fig.* 67), and the Couch Grass (*Triticum repens*), afford good examples of this stem. In some instances such stems serve useful purposes in nature; those of the Sand Sedge or Carex, by spreading through the sand of the seashore and in this way binding it together, prevent it from being washed away by the receding waves. Others, on the other hand, like those of the Couch Grass, are the pest of the agriculturist, who finds it very difficult to destroy such stems by cutting them into pieces, for every node is capable of developing a leaf-bud and roots, and therefore each of the pieces into which they may thus be divided will become an independent individual. Such a process, instead of destroying the plants, only serves the purpose of still further multiplying them by placing the separated parts under more favourable circumstances for development.

FIG. 67.

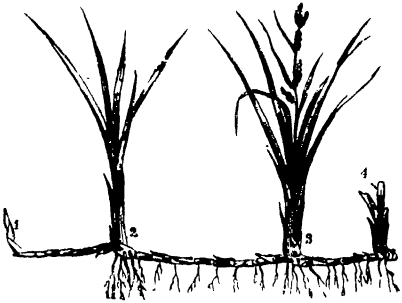


Fig. 67. Creeping stem of the Sand Carex (*Carex arenaria*). 1. Terminal bud by which the stem continues to elongate. 2, 3, 4. Shoots produced from former buds.

c. *The Tuber* (*figs.* 68 and 69). This is a subterranean stem or branch, arrested in its growth, and excessively enlarged by the deposition of starch or other nutritious substances in its tissue. It has upon its surface a variable number of little buds, or *eyes*, as they are sometimes called, from which new plants are ultimately formed. The presence of these buds indicates its nature as a kind of stem. It is a modification which has for its purpose the propagation of the plant. Numerous tubers are formed on each parent plant, becoming separated from it at maturity. Each gives rise to one or more young shoots from its buds. During the formation or development of the tuber a large amount of starch and other nutritive material is stored in its substance to support these young shoots during their early development till they emerge into the air, expand their leaves, and put out adventitious roots. The purpose of the modification is similar to that of the fleshy biennial root, which has already been described

FIG. 68.

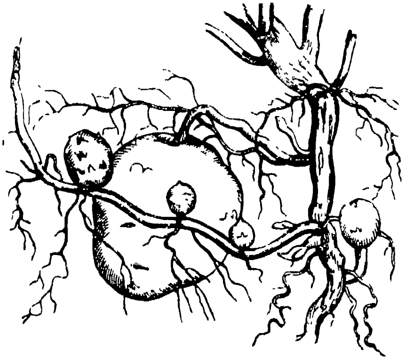


Fig 68. Tubers of the common Potato (*Solanum tuberosum*).

(page 21). The Potato (*fig.* 68) and Jerusalem Artichoke (*fig.* 69) afford good illustrations of tubers.

Though normally growing underground, tubers sometimes appear in the axils of cauline leaves. This is generally a consequence of the destruction of the subterranean tubers.

In certain plants, such as some epiphytic Orchids, a portion of the *sub-aerial* stem may be thickened, the thickening sometimes being confined to one internode, sometimes extending to more than one. This thickening, which resembles a tuber, is often spoken of as a *pseudo-bulb* (*fig.* 33, *b*).

FIG. 69.

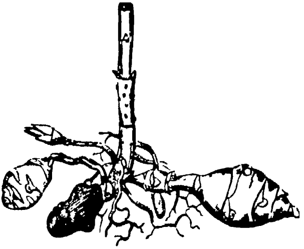


Fig. 69. Tubers of the Jerusalem Artichoke (*Helianthus tuberosus*).

d. *The Bulb.*—This is a shortened, usually subterranean stem or branch, generally in the form of a rounded or flattened plate or disc (*figs.* 70-72, *a*), which bears on its surface a number of fleshy scales or cataphyllary leaves; or it may be considered as a subterranean bud of a scaly nature which sends off roots or rootlets from below (*fig.* 72, *b*), and a flowering stem upwards (*fig.* 70, *p*, and *figs.* 71 and 72, *d*). The scales are generally more or less thickened by deposition of nutritive matters; these, therefore, become reservoirs of nutriment for the future use of the plant, just as in other cases the enlarged stems and roots serve a similar purpose. The true bulb is only found in Monocotyledons, as in the Lily (*figs.* 71 and 72), Onion (*fig.* 73), and Tulip. The scales of a bulb, like the leaves of a branch, often have new bulbs developed in their axils (*fig.* 70, *b*): these are called by gardeners *cloves*, and their presence is an additional proof of the homology of a bulb with a branch or bud.

FIG. 70.

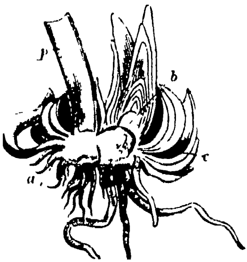


FIG. 71.

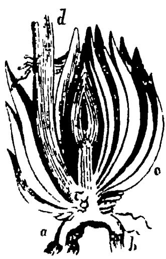


FIG. 72.

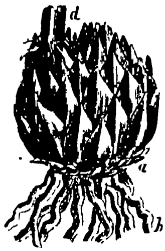


Fig. 70. Vertical section of the scaly bulb of the Lily. *a.* Shortened axis or stem. *b.* Lateral bulb or clove. *p.* Flowering stem. *c.* Scales.——*Fig.* 71. Vertical section of the scaly bulb of the Lily.——*Fig.* 72. Scaly bulb of the Lily. *a.* Shortened axis or stem. *b.* Fibrous roots. *c.* Scales. *d.* Flowering stem. The letters refer to the same parts in the two latter figures.

Bulbs may be commonly distinguished as *tunicated* (*fig.* 73), and *scaly* (*figs.* 71 and 72). The *tunicated bulb* is well seen in the Squill and Onion (*fig.* 73). In this kind of bulb the inner scales, which are thick and fleshy, enclose one another in a concentric manner, and are covered externally by thin and membranous ones, which form a covering or *tunic* to them; hence the name *tunicated* or *coated*, which is applied to it. In the *scaly* or *naked* bulb (*figs.* 71 and 72) there are no outer dry scales; it is composed of thick, fleshy leaves, which overlap one another.

The young bulbs (*cloves*) (*fig.* 70, *b*), which are developed in the axils of the scales of bulbs, in some cases remain attached to their parent, which they then commonly destroy by absorbing all its stored-up nutriment; in others they become separated in the course of growth, and form independent plants.

Small bulbs are sometimes developed in the axils of aerial leaves. They are buds whose leaves have become fleshy. They separate from their parent and produce new individuals. The same phenomenon has been mentioned as occurring in the case of tubers. These *aerial bulbs*, or *bulbils*, are met with in some species of Lily (*fig.* 74, *a*, *a*), the Coralwort (*Dentaria bulbifera*), and Pilewort (*Ranunculus Ficaria*).

c. *The Corm.*—This form of stem, like the true bulb, is chiefly found in Monocotyledons, as the Colchicum (*fig.* 77) and Crocus (*figs.* 75 and 76). It is an enlarged solid subterranean stem, rounded in shape, composed of two or more internodes, and commonly covered externally by a few thin membranous scales or cataphyllary leaves. It differs from the bulb by the stem becoming large and fleshy, and the scales being reduced to thin membranes. The corm shows itself to be a kind of stem by producing from its surface one or more buds, in the form of young corms, as in the Crocus (*fig.* 75, *a*, *b*), where they proceed from the apex, *c*, and ultimately destroy their parent by feeding upon its accumulated nutriment. These new corms, in the next year, produce others near their apices, and these by developing at the expense of their parents also

FIG. 73.

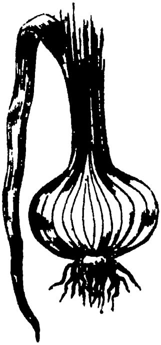


FIG. 74.

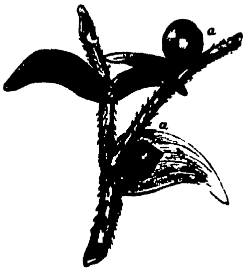


Fig. 73. Tunicated bulb of the Onion.——*Fig.* 74. Stem of a species of Lily (*Lilium bulbiferum*) bearing bulbils or bulblets, *a*, *a*, in the axils of its leaves.

destroy them in like manner, and again form other corms by which they are themselves destroyed. In this manner the new corms, as they are successively developed from the apices of the old ones, come gradually nearer and nearer to the surface of the earth.

FIG. 75.

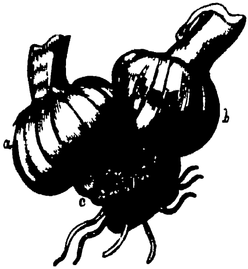


FIG. 76.

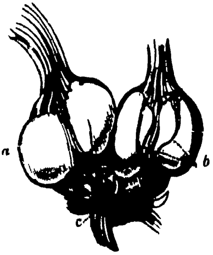


Fig. 75. Corms of *Crocus sativus.* *a*, *b*. The new corms, arising from *c*, the apex of the old or parent corm. —*Fig.* 76. Vertical section of the former. The letters refer to the same parts.

FIG. 77.

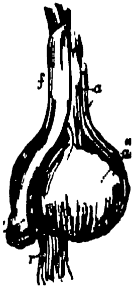


Fig. 77. Colchicum. *r*. Roots or rootlets. *f*. Leaf. *a*. Shrivelled remains of last year's corm. *a''*. Corm of the present year. *a'''*. Commencement of the corm of next year.

In the Colchicum (*fig.* 77), the new corm *a'''* is developed on one side of the old corm near its base, instead of from the apex, as in the Crocus. This also feeds upon its parent, and ultimately destroys it, and is in like manner destroyed the next year by its own progeny. When we take up such a corm carefully, we can find the shrivelled corm of last year (*fig.* 77, *a*), and *a''*, that of the present season, which, if cut vertically, shows *a'''*, next year's corm in a young condition.

Another type of the corm is found in the Cyclamen. It is a fleshy expansion of the base of the seedling stem which thickens and enlarges year by year, but does not lengthen, thus becoming a broad thick body. The thickening is confined to the first internode. It bears annually leaves and flowers from its apex, which may be found at the centre of the upper surface. The lower surface produces roots. This kind of corm is always naked, producing no leaves except those of its apical bud.

Like the tuber, the bulb and corm are modifications whose purpose is the propagation of the plant.

SECTION III.—THE SHOOT (*continued*).

B. The Leaves.

1. GENERAL DESCRIPTION OF THE PARTS OF THE LEAF.

We have seen that the vegetative appendages which arise upon the stem are of two kinds, those which are *like* and those which are *unlike* the axis itself. A leaf may be defined as an appendage borne upon an axis from which it differs in its structure and organisation. Like the stem itself it is capable of branching, and its branches show similar modes of origin to those of the branches of the axis. The ultimate shape of the leaf, indeed, may be traced to its behaviour in this respect. It differs from the stem in the degree to which its branching may be carried, seldom showing branches of more than the second or third order.

The part of the stem or branch from which a leaf arises is called a *node*, and the space between two nodes an *internode*. The portion of the leaf next the stem is termed the *base*, the opposite extremity the *apex*, and the lines connecting the base and apex the *margins*. The leaf, being commonly of a flattened nature, has only two surfaces; but when *succulent* it has frequently more than two. The terms upper and lower are applied to the two surfaces of ordinary leaves, because in by far the greater number of plants such leaves are placed horizontally, so that one surface is turned upwards, and the other downwards. There are certain leaves, however, which are placed vertically, as those of some species of *Eucalyptus*, in which case the margins are turned upwards and downwards instead of the surfaces. The angle formed by the union of the upper surface of the leaf with the stem is called the *axil*, and everything which arises out of that point is said to be *axillary* to the leaf; if anything springs from the stem above or below the axil, it is *extra-axillary*; or, as more generally described when above, *supra-axillary*; when below, *infra-axillary*.

Duration and Fall of the Leaf.—The leaf varies as regards its duration, and receives different names accordingly. When it falls off soon after its appearance, it is said to be *fugacious* or *caducous*; if it lasts throughout the season in which it is developed, it is *deciduous* or *annual*; if beyond a single season, or until new leaves are developed, so that the plant is never without leaves, it is *persistent*, *evergreen*, or *perennial*.

The parts of the leaf. – The axis of the leaf may be termed a *phyllopodium*; it is capable of very varied development, and its region of active growth is seldom altogether apical as in the stem axis. It commences apically, but this apical growth is usually superseded by a basal growth, which continues after the former has ceased. This is especially well seen in the long narrow leaves of many Monocotyledons.

In the phyllopodium three regions may be distinguished:— the so-called *leaf-base*, or *hypopodium*, comprising that part which is attached to the stem; the *lamina*, or *epipodium*, which is the usually flattened terminal portion, which forms what is often alluded to generally as the leaf proper; and an intermediate portion, the *mesopodium* or *petiole*. Either the epipodium or the mesopodium may be absent.

FIG. 78.

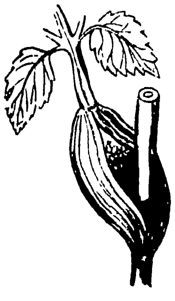


FIG. 79.

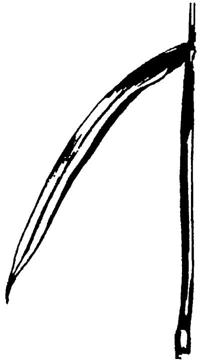


Fig. 78. Amplexicaul base of the leaf in Fool's Parsley.— *Fig.* 79. Sheathing leaf of a Grass.

The leaf in one or all of these regions generally takes the form of a flattened expansion, owing to the distribution of growth in the phyllopodium leading to the development of a thin wing along two of its sides in a lateral plane. This wing is usually, though not always, confined to the epipodium, which consequently is generally the flat part. The branches of the epipodium, when present, are also winged, and the relative development of the main axis, its branches and their wings, causes the various forms of the leaf-blade.

In the simplest forms of leaf the phyllopodium does not branch nor show any division into the three regions spoken of. It is then a cylindrical structure as in *Pilularia* and *Sedum*, or a flattened one with no evident wings as in many Monocotyledons, or a winged one as in some of the Gymnosperms. When it branches, the branches usually arise upon the epipodium, and are developed either acropetally or basipetally, according to the position of the growing part.

FIG. 80.

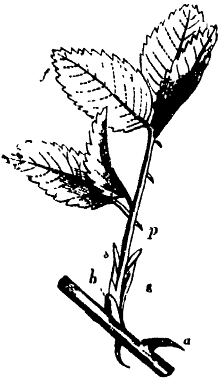


Fig. 80. A portion of a branch, *r*, of the common Rose (*Rosa canina*). *a*. A prickle. *b*. Bud in the axil of a compound leaf, *f*, with stalked leaflets. *p*. Petiole. *s*, *s*. Adnate or adherent stipules.

In leaves which show a differentiation into the three regions spoken of, each region shows certain peculiarities.

The Hypopodium or Leaf-base.—This is often very difficult to distinguish from the stem. The tissues of both are continuous, and unless some outward peculiarity appears the two cannot be accurately delimited. Very often, however, the point of union of the two is marked by a swelling of the hypopodium forming a sort of cushion called a *pulvinus*, and in some cases it appears as a definite articulation. When the leaf-base is broad, this swelling extends for a considerable distance round the stem. Such leaves can be detached very readily, and leave a kind of scar which can be noticed on the stem after the leaf has fallen off (*fig.* 37). This cushion may form a kind of sheath, almost embracing the stem, as in the common *Pelargonium*. It may be somewhat membranous and completely encircle the stem, as in the Fool's Parsley (*fig.* 78). These modes of arrangement are known as *semi-amplexicaul* and *amplexicaul*, respectively.

Frequently the leaf-base bears a pair of lateral branches, which often become winged like the epipodium, but may assume other forms. These are known as *stipules*. They have the same structure as the blades of leaves. They are often overlooked from their small size; sometimes, however, they are very large, as in the Pansy (*fig.* 81), and in the common Pea (*fig.* 82).

In the leaves of *Lathyrus Aphaca* (*fig.* 186) the axis of the phyllopodium does not become winged, but the stipules, *s*, *s*, are here very large and perform all the functions discharged usually by the leaf-blade.

Stipules either remain attached as long as the lamina, when they are said to be *persistent*; or they fall off soon after its expansion, in which case they are *deciduous*. In the Beech, the Fig, the Magnolia, &c., they form the *tegmenta* or protective coverings of the buds, and fall off as these open.

FIG. 81.

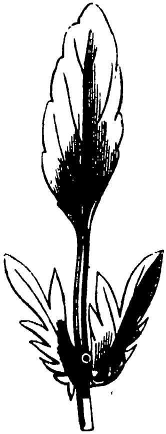


FIG. 82.

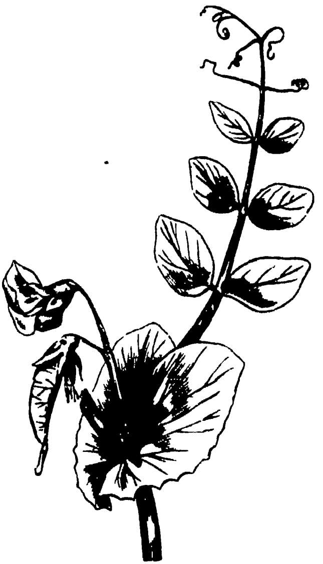


Fig. 81. Petiolate leaf of Pansy (*Viola tricolor*) with large caulinary stipules at its base.——*Fig.* 82. A portion of the flowering stem of the common Pea, with a pinnate leaf terminated by a tendril, and having two large stipules at its base, the lower margins of which are dentate.

A curious modification of the normal arrangement of the stipules is seen in plants belonging to the Natural Order *Polygonaceæ*. The two stipules cohere by their outer and inner margins so as to form a complete sheath which encircles the stem above the insertion of the leaf. They form what is known as an *ochrea* (*fig.* 85, *d*). The anterior margins are not united in *Astragalus* (*fig.* 83). In *Houttuynia* (*fig.* 84) the posterior margins are not united, so that the two stipules are coherent to form a foliaceous body which apparently stands in the axil of the leaf.

FIG. 83.

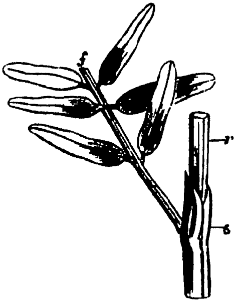


FIG. 84.

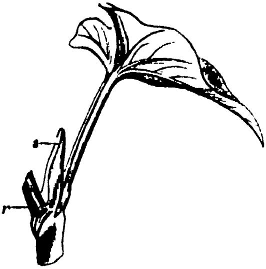


Fig. 83. A portion of the stem, *r*, and leaf, *f*, of the *Astragalus Onybrichis*. *s*. Stipules.——*Fig.* 84. A portion of the stem, *r*, and leaf, *f*, of *Houttuynia cordata*. *s*. Axillary stipule.

The stipules are sometimes modified to form spines, much resembling the thorns of the stem, as in *Robinia* (*fig.* 87).

FIG. 85.

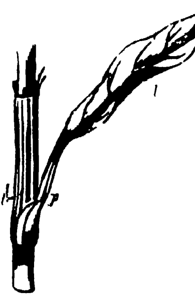


FIG. 86.

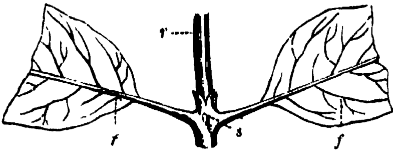


Fig. 85. Leaf and piece of the stem of *Polygonum Hydropiper*. *l*. Lamina or blade. *p*. Petiole. *od*. Ochrea.——*Fig.* 86. A portion of a branch, *r*, with two opposite leaves, *f*, *f*, of *Cephalanthus occidentalis*. *s*. Interpetiolar stipule.

In many species of *Smilax* they take the form of tendrils (*fig.* 88).

Stipules are very rare in Monocotyledons; among the Cryptogams they are present only in the Marattiaceæ, a group of the Ferns. When they are absent the leaf is said to be *exstipulate.*

The Mesopodium or Petiole.—According to the presence or absence of this portion of the leaf-axis, leaves are said to be *stalked* or *sessile.* When the petiole is present it is as a rule more or less cylindrical, but frequently it is almost semicircular in section, the upper surface being flattened and sometimes grooved. It may be very short or considerably elongated. In the Grasses it surrounds the stem in the form of a sheath (*fig.* 79), and where the blade and petiole join there is found a membranous appendage, lying parallel to the blade. To this the name of *ligule* has been given. It is either entire or incised in various ways. In the Aspen (*Populus tremula*), the petiole is flattened in a line at right angles to the blade, and is thus one of the causes of the peculiar mobility of the leaves; in other plants it is flattened in a horizontal direction. In aquatic plants the petiole is frequently more or less dilated from the presence of a number of air cavities, as in *Pontederia*; such petioles, by diminishing the specific gravity of the plants in which they are found, enable them to float readily in the water. In many plants the petiole is winged like the leaf-blade, though generally not to

FIG. 87.

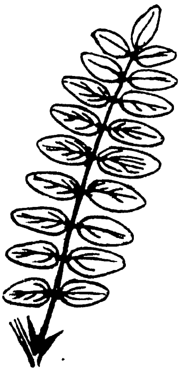


FIG. 88.

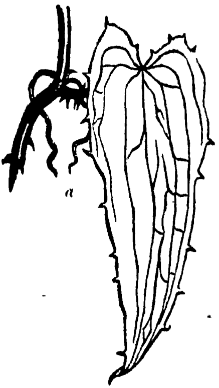


Fig. 87. Compound leaf of *Robinia Pseud-acacia*, with spiny stipules at its base.——*Fig.* 88. Modified stipules of *Smilax*, forming tendrils, *a*.

the same extent. Instances are found in the Venus's Fly-trap (*fig.* 89) and the Orange (*fig.* 90).

In some cases the epipodium is not developed, or falls off at a very early age. The petiole is then usually very strongly winged, and takes on the ordinary function of the blade. This is seen in some of the Leguminosæ; *Lathyrus Nissolia* of the British flora is an instance. It is much more conspicuous in many of the Australian Acacias; some of their leaves show the ordinary pinnate form, others are similar with the petiole winged, and others show the ~~winged petiole~~ only, the epipodium having disappeared. Such a winged petiole is called a *phyllode*; it can be distinguished from a leaf-blade by the fact that its flattened surfaces are placed laterally to the stem. A phyllode must not be confused with the variety of stem previously described as a phylloclade.

FIG. 89.

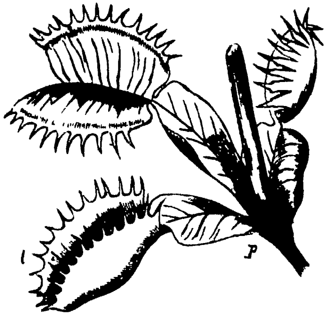


FIG. 90.

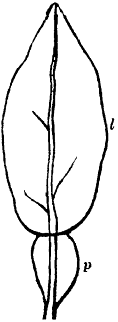


Fig. 89. A portion of the stem with some leaves of Venus's Fly-trap (*Dionæa muscipula*). *l.* Lamina. *p.* Winged petiole.——*Fig.* 90. Leaf of Orange (*Citrus Aurantium*). *p.* Winged petiole articulated to the lamina, *l.*

In some cases the petiole and leaf-base are winged in a plane at right angles to that of the blade, and the stem also has a wing extending for some distance below each node. These wings meet at the node and present the appearance of the wing of the leaf extending down the stem. Such a leaf is said to be *decurrent*. An example is seen in some Thistles (*figs.* 93 and 94).

The Epipodium or Leaf-blade.—As already indicated, this part of the leaf shows a very great variety of form, ranging from a cylindrical outgrowth to a very much dissected and flattened one. It usually consists of an axis which shows more or less evidence of branching, the axis itself and its several branches either becoming winged, or remaining more or less cylindrical. Indeed, the epipodium of the leaf is a branch system rather than a simple outgrowth.

The main axis, though often winged, is not always so. It may be cylindrical in form with the branches or *pinnæ* arranged along it. The branches of the first order also frequently remain cylindrical, and their secondary branches are the only flattened portions. Sometimes, as in the leaf of the Fennel, all the branches are cylindrical, and there is no flattened expansion, the leaf appearing almost filamentous. Similar filamentous leaves are found in some of the Water Crowfoots.

FIG. 91.

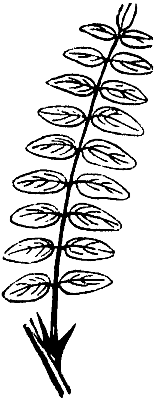


FIG. 92.

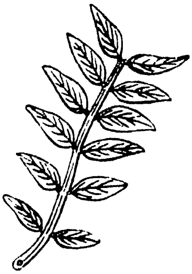


Fig. 91. Imparipinnate or unequally pinnate leaf of *Robinia*, with spiny stipules.—*Fig.* 92 Paripinnate leaf.

The branching of the epipodium proceeds on the same lines as that of the stem; it is dichotomous in some of the Hymenophyllaceæ, a family of Ferns; it is monopodial in many Dicotyledons, where its branches are produced either acropetally or basipetally, according to the position of the region of active growth; it is cymose in many other Dicotyledons. It is usual to describe the types of leaves derived from the racemose and cymose modes of branching as *pinnate* or *palmate* respectively, both showing considerable variety of form.

When the axis of the epipodium remains cylindrical, and its branches of the first order become separately winged, the appearance is presented of a number of small winged expansions, each attached to the axis and each apparently independent. Such a leaf is called *compound*. According to the nature of the branching we get the *pinnate* or the *palmate* leaf, the separate branches being called *leaflets*. When the apex of the epipodium of the pinnate leaf is winged like the branches, the leaf is said to be *imparipinnate* (*fig.* 91); when there is no terminal winged expansion, it is *paripinnate* (*fig.* 92). Various forms of leaves of both types will be described later.

FIG. 93.

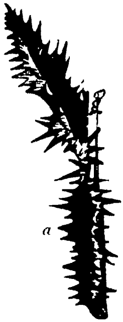


FIG. 94.

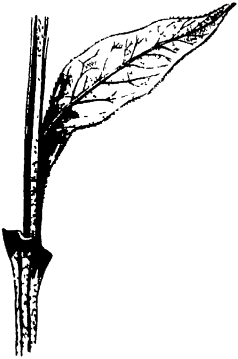


Fig. 93. Decurrent leaf-base of a species of Thistle. *a*, Wing of stem.
Fig. 94. Decurrent leaves of the Comfrey.

FIG. 95.

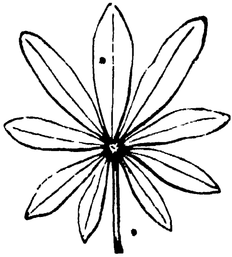


FIG. 96.

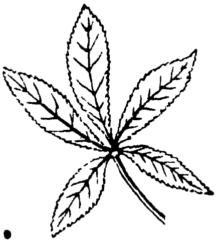


Fig. 95. Digitate leaf of a Lupin (Palmate type).—*Fig.* 96 Digitate leaf of *Potentilla*.

When the axis is winged as well as its branches, the wings of both are usually more or less united, giving rise to the appearance of a single much-divided lamina. Such leaves, however much divided, are classed as *simple* leaves. In many cases with much-branched epipodia the main axis and the secondary axes are not winged, while the tertiary axes and the ultimate branches are both winged, and show a fusion of the wings, as in *fig.* 97. Such a leaf shows a combination of the simple and compound forms; it is common among the Umbelliferæ.

The fusion of the wings of the axis and its branches shows almost every stage of completeness from the so-called compound leaf to the simplest flattened expansions. Indeed, in many of the latter the only indication of branching that can be noticed is found in the disposition of the vascular bundles which enter each branch, giving rise to a pinnate or palmate venation, as will be described later.

FIG. 97.

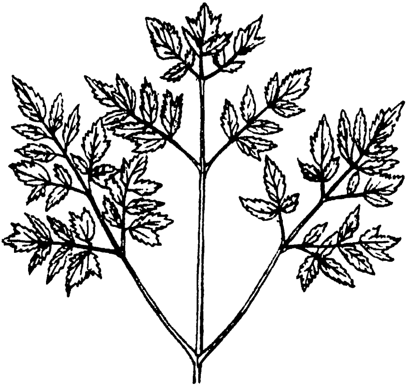


Fig. 97. Tripinnate leaf.

When the fusion of the wings is not complete, the several branches are known as *lobes*. It is usual to give different names to the apparent divisions of the leaf based on the degree of the fusion; if they reach to about midway between the margins and midrib (*fig.* 113), or petiole (*fig.* 102), they are properly called *lobes*, and the intervals between them *fissures*; in composition the terms *-fid* or *-cleft* are used; if the divisions reach nearer to the base, or midrib (*fig.* 99), they are termed *partitions*, and the leaf is *-partite*; if almost down to the base, or midrib, they are called *segments* (*fig.* 100), and the leaf is *dissected*, or in composition *-sected*.

When the axis of the epipodium bears monopodially branches of the first order, which give rise in turn to the pinnæ, and all are winged, the wings showing similar degrees of fusion to those described above, we have forms which are described as *bipinnatifid*, *bipinnatipartite*, or *bipinnatisected* respectively. Further degrees of branching and fusion are indicated by the terms *tripinnatifid*, &c. When the branching is very complete, and

FIG. 98.

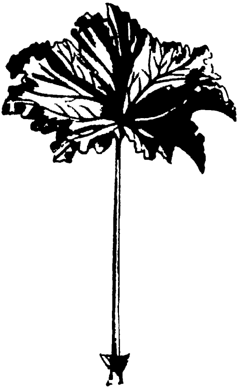


FIG. 99.

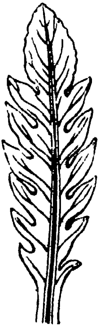


FIG. 100.

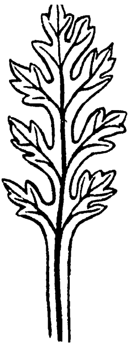


FIG. 101.

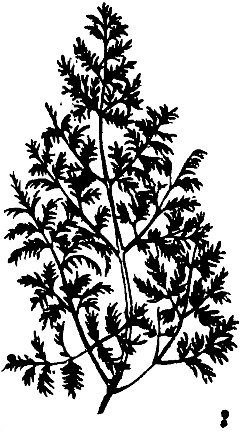


FIG. 102.

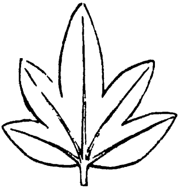


Fig. 98. Crisped or curled leaf of a species of Mallow (*Malva*)——*Fig.* 99. Pinnatipartite leaf of a species of Valerian (*Valeriana dioica*).——*Fig.* 100. Pinnatisected leaf of a species of Poppy (*Papaver Argemone*).——*Fig.* 101. A decompound leaf.——*Fig.* 102. Palmate leaf of a species of Passion-flower (*Passiflora*).

the ultimate wings but little developed, the leaf is called *decompound*. When the branching is not monopodial but cymose, we have *palmate*, *palmatifid*, or *palmatisected* leaves, the degree of fusion between the wings of the branches being thereby indicated. In such leaves the primary axis of the phyllopodium does not enter into the composition of the lamina. Cymose branch systems sometimes show branches of the third order, as in the *pedate* or *pedatipartite* leaf (*fig.* 104).

It is not unusual to find both types of branching represented in the same leaf. Frequently in the palmate varieties we find that, while the main branches arise cymosely, each forms a monopodium. The nature of the branching may generally be ascertained by an inspection of the arrangement of the veins or vascular bundles, as shown in *fig.* 103, the palmatifid leaf of the Castor-oil plant. Here the phyllopodium gives rise cymosely to seven branches, each of which develops monopodially.

FIG. 103.

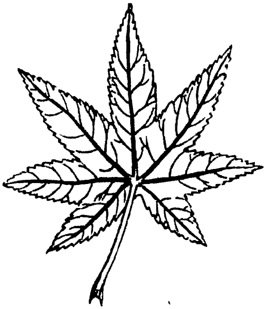


FIG. 104.

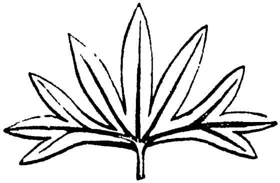


Fig. 103. Palmatifid leaf of the Castor-oil Plant (*Ricinus communis*).——*Fig.* 104. Pedatipartite leaf.

Generally the branches of the epipodium all lie in one plane, so that the leaf is flattened with its face towards the stem. In a particular variety of the palmate form known as the *peltate* leaf (*fig.* 105) this rule is departed from, the petiole being apparently attached to the centre of the leaf-blade, the plane of which is thus almost at a right angle to the direction of the stalk. This is due to the fact that the younger branches grow out in front of the petiole, instead of in the usual lateral plane, and their wings being coherent with each other, the petiole becomes apparently attached to the middle of the lamina.

When the epipodium remains cylindrical, and bears only branches of the first order which are winged, constituting a number of leaflets, these may show at their bases certain outgrowths resembling the stipules of the primary leaf-base. These are known as *stipels*; they are present in certain Leguminosæ, as *Phaseolus*.

When the mesopodium or petiole is absent, the hypopodium or leaf-base may be winged, and its wings continuous with those of the lamina. The stem thus seems to be surrounded by the expanded base of the latter. If two leaves arise on the stem at the same node, their wings sometimes coalesce. We have thus formed the varieties known as *auriculate*, *perfoliate*, or *connate* leaves (*figs.* 106 and 107).

The flattened portion of the epipodium is always found to be strengthened and supported by certain strands of woody tissue which traverse it in various directions. In thin leaves these are visible as projections on the under surface, but in thick or succulent ones they are embedded in the substance of the blade. These strands are known as the *veins*, and their arrangement constitutes the *venation* of the leaf. The latter depends broadly on the mode of branching which characterises the epipodium.

FIG. 105.

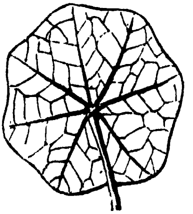


FIG. 106.

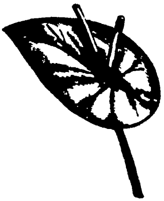


FIG. 107.

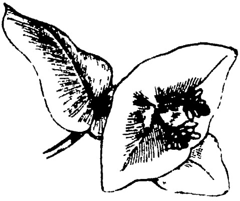


Fig. 105. Peltate leaf of *Tropæolum*.—*Fig.* 106. Perfoliate leaf of a species of Hare's-ear (*Bupleurum rotundifolium*).—*Fig.* 107. Connate leaves of a species of Honeysuckle (*Lonicera Caprifolium*).

There are two marked modifications of venation. In the *first modification* the fibro-vascular tissue, as it enters the lamina either as a single main vein or several similar ones, breaks up into a network of branches (*figs.* 108 and 110). In the *second modification*, a midrib runs from the base to the apex of the lamina, giving off from its sides other veins, which go out to the margins, running parallel to each other, and are simply connected by unbranched veinlets (*figs.* 111, *b*, and 118); or it divides at once into several veins or ribs, which proceed from the base to the apex (*fig.* 116) or margins (*fig.* 117) of the blade, more or less parallel to one another, and are in like manner connected only by simple parallel unbranched veinlets (*fig.* 111, *a*). The leaves which exhibit the first modification of venation are called *reticulated* or *netted-veined* leaves, and occur universally in Dicotyledons; and those which present the second modification are termed *parallel-veined* leaves, and are characteristic, with some few exceptions, of Monocotyledons.

Fig. 108.

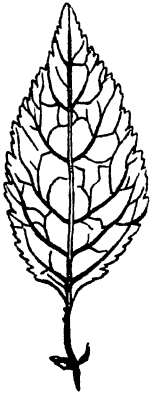


Fig. 110.

Fig. 109.

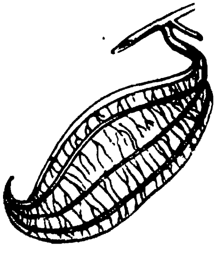


Fig. 111.

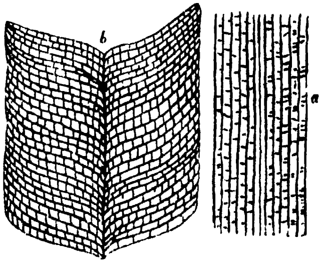


Fig. 108. Leaf of the Cherry with lamina, petiole, and stipules. The lamina has serrate margins, and a large central vein or midrib is seen to proceed from the petiole to the apex of the leaf, and to give off from its sides the other veins (*pinnately veined*).——*Fig.* 109. Ribbed leaf of Cinnamon with entire margins.——*Fig.* 110. Leaf of the Melon with dentate margins. The venation is said to be radiated or palmately veined.——*Fig.* 111. *a* Parallel venation of a grass; this variety of venation is commonly called straight-veined. *b*. A variety of parallel venation sometimes termed curve-veined, as seen in the Banana.

(1) *Varieties of Reticulated or Netted Venation.*

There are two principal varieties of this kind of venation, namely the *feather-veined* or *pinnately veined*, and the *radiated* or *palmately veined*.

A. *Feather-veined or Pinnately veined.* –In this variety the main vein either gives off lateral ones which proceed at once to the margins (*figs.* 112 and 113), and are connected by numerous branching veinlets, as in the leaves of the Beech, Spanish Chestnut, Holly, Oak; or it gives off branches from its sides, which proceed at first towards the margins, and then curve towards the apex, terminating finally within the margins, with which they are connected by small veins, as in the Dead-nettle (*fig.* 114) and Lilac.

FIG. 112.

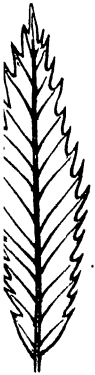


FIG. 113.

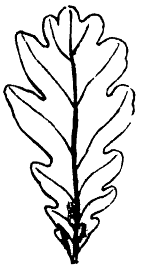


FIG. 114.

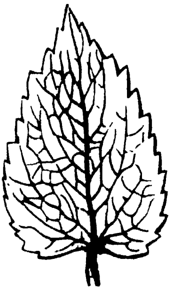


FIG. 115.

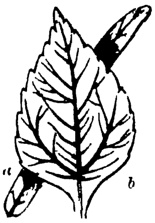


Fig. 112. Feather-veined leaf of the Spanish Chestnut.——*Fig.* 113. Feather-veined leaf of the Oak. Its lobes are arranged in a pinnatifid manner.——*Fig.* 114. Leaf of the Dead-nettle. The venation is the true-netted, and its margins are serrate.——*Fig.* 115. *a.* Linear leaf. *b.* Triple-ribbed leaf of the common Sunflower.

B. *Radiated* or *Palmately veined.*—This name is applied to a leaf which possesses two or more strong veins that arise at or near the base of the lamina, and diverge from one another towards its margins, being connected by branching veins, as in the Melon (*fig.* 110) and Castor-oil plant (*fig.* 103). The *ribbed venation*, as seen in the Cinnamon (*fig.* 109), is but a modification of this variety, in which the ribs, instead of diverging from one another, run in a curved manner from a point at or near the base of the blade to the apex, towards which they converge, such ribs being connected together by branching veins.

The varieties of venation correspond to the modes of branching of the phyllopodium already described, the fusion of the wings of the branches being almost or quite complete.

(2) *Varieties of Parallel Venation.*

There are certain characteristic variations of parallel venation. The main veins may either proceed in a somewhat parallel direction from the base to the apex of the lamina, to which point they converge more or less (*fig.* 116), or they may diverge from one another towards the circumference of the blade (*fig.* 117). The leaves of Grasses, Lilies, and the common Flag may be taken as examples of the first variety; and those of many Palms (*fig.* 117) of the second.

FIG. 116.

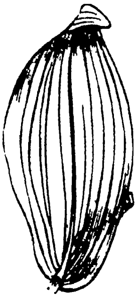


FIG. 117.

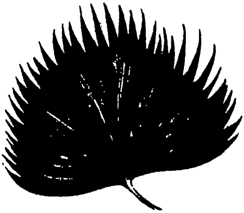


FIG. 118.

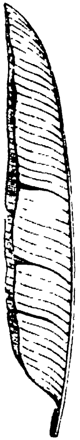


FIG. 119.

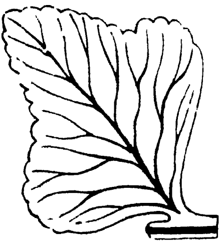


Fig. 116. Leaf showing the variety of parallel venation usually called straight-veined; the margins are entire.——*Fig.* 117. Straight-veined variety of parallel venation, as seen in the leaf of the Fan Palm (*Chamærops*).——*Fig.* 118. Curve-veined variety of parallel venation, as seen in the Banana.——*Fig.* 119. Forked venation of a Fern leaf; the margins are crenate.

Or the leaves may have a prominent midrib, as in the feather-veined variety of reticulated venation, giving off from its sides along its whole length other veins, which proceed parallel to each other in a straight or curved direction towards, and lose themselves in, the margins (*figs.* 118 and 111, *b*); and are connected, as in the last variety, by unbranched veinlets. The Banana, the Plantain, and allied plants furnish us with examples of this variety. This latter variety is sometimes distinguished as the *curve-veined*, the former being commonly known as the *straight-veined* or *parallel-veined*.

The Shapes of Leaves.

We have seen that the freedom or coalescence of the wings of the epipodium and those of its branches leads to the recognition of two apparently different types of leaf, the *simple* and the *compound*. It will be convenient to discuss the peculiarities of these two kinds separately.

Simple Leaves.

The modifications which simple leaves present as regards their margins, shapes, and other variations of their blades are extremely numerous. They are important chiefly as enabling accurate descriptions to be given of the plant to which they belong, so that its identity may be established and certain of its affinities indicated. In other respects their importance is altogether subordinate. They are usually considered under five heads, as follows: 1. Margins; 2. Incision; 3. Apex; 4. General Outline; 5. Form.

1. *Margins.*—We have already remarked that the condition of the margins is dependent upon the extent to which the wings of the epipodium and its branches are united. If the fusion of the wings of the several axes is complete and extends to their apices, so that the margins are perfectly even, or free from every kind of irregularity, the leaf is *entire* (*figs.* 92 and 116). But when the fusion is not quite complete, and the margins are uneven, we have several modifications, which are distinguished by characteristic terms. If the margins present sharp indentations like the teeth of a saw, and all point to the apex, the leaf is *serrate* (*figs.* 114 and 142), as in the common Dead-nettle; if similar teeth point towards the base, the leaf is described as *retroserrate*; if these teeth are themselves serrate, it is *biserrate* (*figs.* 120, *b*, and 131), as in the Elm and Nettle-leaved Bell-flower; when the margins are minutely serrate,

FIG. 120.

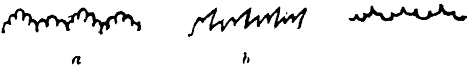


Fig. 120. Diagram of the margins of leaves.
a. Bicrenate. *b*. Biserrate. *c*. Duplicato-dentate.

they are termed *serrulate*, as in *Barosma serratifolia*. When the teeth are sharp, and project almost or quite at right angles to the margin, the leaf is *dentate* or *toothed* (*figs*. 110 and 137), as in the Melon, and the lower leaves of the Corn Bluebottle; when the teeth are themselves divided in a similar manner, it is *duplicato-dentate* (*fig*. 120, *c*). When the teeth are rounded (*figs*. 119 and 143) the leaf is *crenate*, as in the Horseradish and Ground Ivy; if these teeth are themselves crenate it is *bicrenate* (*fig*. 120, *a*); when the leaf is minutely crenate it is said to be *crenulated*. When the margins present alternately deep concavities and convexities it is *sinuated*, as in some Oaks (*fig*. 121). This kind of leaf may be regarded as an intermediate condition between a toothed leaf and one that is pinnatifid (*fig*. 113). When the margins are slightly sinuous or wavy, as in the Holly (*fig*. 122), they are said to be *wavy* or *undulated*; the teeth of the leaves of the Holly are very hard and end in sharp points, forming spines. When the margins are very irregular, being twisted and curled, as in the Garden Endive, Curled Dock, and Curled Mint, they are called *crisped* or *curled* (*fig*. 98).

Fig. 121.

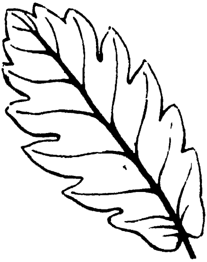


Fig. 122.

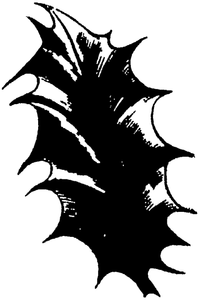


Fig. 121. Sinuated leaf of the Oak.——*Fig* 122. Spiny leaf of the Holly (*Ilex Aquifolium*), with wavy margins.

2. *Incision*.—This term is employed when the margins of the blades are more deeply divided than in the above instances. The divisions are then commonly called *lobes*.

When a pinnately veined leaf is deeply divided, and the divisions are very close and narrow like the teeth of a comb (*fig*. 125), it is said to be *pectinate*, as in the Water Milfoil; when the terminal lobe of a pinnately veined leaf is large and rounded, and the lateral lobes, which are also more or less rounded, become gradually smaller towards the base, it is *lyrate*, or *lyre-shaped*, as in the common Turnip (*fig*. 126); when the terminal lobe is triangular, and the other lobes which are also more or less of the same shape have their points directed downwards towards the base of the lamina, as in the Dandelion (*fig.* 127), the leaf is said to be *runcinate*; when a lyrate leaf has but one deep recess on each side, so that it resembles a violin in shape, it is termed *panduriform* or *fiddle-shaped*, as in the Fiddle Dock (*fig.* 128).

Modifications of palmately veined leaves are also frequent. When the blade of such a leaf is composed of five or more branches whose wings are united about halfway from the base to the tip, so that the whole has a resemblance to the palm of the hand with spreading fingers, the leaf is termed *palmate*, as in some species of Passion-flower (*fig.* 123). When the union is less complete, as in the Castor-oil plant, the leaf is described as *palmatifid* (*fig.* 124). There is little difference between those two forms, and it is better to apply

FIG. 123.

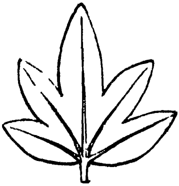


FIG. 124.

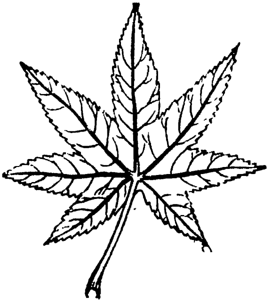


Fig. 123. Palmate leaf of a species of Passion-flower (*Passiflora*).
Fig. 124. Palmatifid leaf of the Castor-oil plant (*Ricinus communis*).

the term 'palmate' to compound leaves. These forms lead on to the compound leaf already described as *digitate*. Other intermediate forms occur. The *pedate* leaf (*fig.* 104) is a variety of the palmate; the branching here is cymose; the apex of the epipodium forms the largest lobe; from under it a branch proceeds on each side; from under each of these a single branch is given off on the lateral flank, which itself bears another arising similarly. The wings of the epipodium and its branches are all united at their bases, but the union extends further towards the apices of the youngest lateral ones. The name is derived from a fanciful resemblance to the claw of a bird.

Besides these modifications of palmately veined leaves, variations also occur, in consequence of the lobes or primary branches of the lamina becoming themselves branched either in a pinnate or palmate manner. Descriptive terms are applied to these forms, which will be readily understood.

3. *Apex.*—Various forms of this are described as follows. The apex is *obtuse* or *blunt* when it is rounded (*figs.* 138 and 140), as in the Primrose; it is *retuse* when it is obtuse with a broad shallow notch in the middle, as in the Red Whortleberry (*Vaccinium Vitis-idæa*) and the leaflets of Logwood; when under the same circumstances the notch is sharp, or nearly triangular, it is *emarginate*, as in some species of *Cassia* (*fig.* 129), and in the common Box (*Buxus sempervirens*). When the lamina terminates very abruptly, as if it had been cut across in a straight line, the apex is *truncate*, as in the lip of the Tulip-tree (*fig.* 130); if under the same circumstances the termination is ragged and irregular, as if it had been bitten off, it is *præmorse*, as in the leaf of *Caryota urens*. When the apex is sharp, so that the two margins form an acute angle with each other (*figs.* 132 and 139), it is *acute* or *sharp-pointed*; when the point is very long, and tapering (*fig.* 137), it is *acuminate* or *taper-pointed*, as in the leaf of the White Willow and common Reed; when it tapers gradually into a rigid point, it is *cuspidate*, as in many *Rubi*. When the apex, which is then commonly rounded, has a short hard or softened point standing on it, it is *mucronate*

FIG. 125.

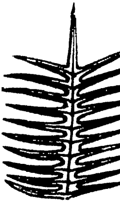


FIG. 126.

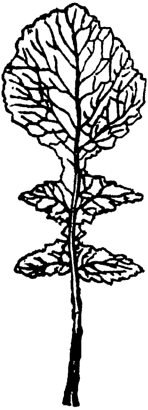


FIG. 127.

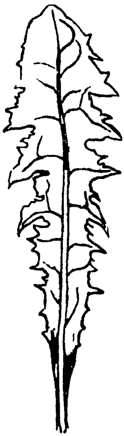


FIG. 128.

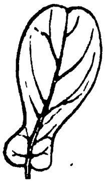


Fig. 125. Pectinate or comb-shaped leaf.——*Fig.* 126. Lyrate leaf of the common Turnip (*Brassica Rapa*).——*Fig.* 127. Runcinate leaf of the Dandelion (*Taraxacum officinale*).——*Fig.* 128. Fiddle-shaped leaf of *Rumex pulcher*.

(*fig.* 136), as in the leaf of *Statice mucronata* and *Lathyrus pratensis.*

4. *General Outline or Figure.*--By the general outline or shape of the lamina we mean the superficial aspect or the figure which is described by its margins. The development of the wings is usually nearly equal on the two sides of the midrib or petiole, so that the lamina of the leaf is in most instances nearly symmetrical and of some regular figure; in which case the leaf is said to be *equal* (*figs.* 137-140). When, as occasionally happens, the wing is more developed on one side than on the other, the leaf is termed *unequal* or *oblique* (*figs.* 129 and 131); this is remarkably the case in the species of *Begonia* (*fig.* 132). Generally speaking, entire leaves with parallel or pinnate venation are longer than broad; while those which are palmately veined are more or less rounded, or broader than long.

Fig. 129.

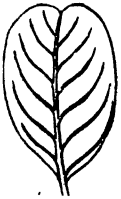


Fig. 130.

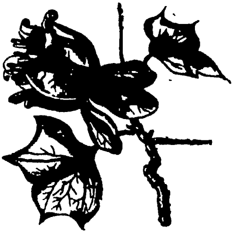


Fig. 129. Leaflet of a species of *Cassia.* It is obovate in figure or outline, somewhat oblique at the base, and emarginate at its apex.——*Fig.* 130. Branch of the Tulip-tree (*Liriodendron tulipiferum*) with flower and leaves. The latter terminate abruptly, hence they are said to be *truncate.*

When the lamina of a leaf is nearly of the same breadth at the base as it is near the apex, narrow, and with the two margins parallel (*figs.* 115, *a*, and 133), the leaf is called *linear*, as in the Marsh Gentian (*Gentiana Pneumonanthe*) and most Grasses; when a linear leaf terminates in a sharp rigid point like a needle, as in the common Juniper (*fig.* 135), and many of our Firs and Larches, it is *acerose* or *needle-shaped.* When the blade of a leaf is very narrow and tapers from the base to a very fine point, so that it resembles an awl in shape, as in the common Furze (*Ulex europæus*), the leaf is *subulate* or *awl-shaped.* When the blade of a leaf is broadest at the centre, three or more times as long as broad, and tapers perceptibly from the centre to both base and apex, as in the White Willow (*Salix alba*), the leaf is *lanceolate* (*fig.* 134); when it is a little longer than broad, of about the same breadth at equal distances from its base and apex, which are slightly acute, it is oval or *elliptical*, as in the Lily-of-the-Valley (*Convallaria majalis*) (*fig.* 142); if under the same circumstances it is obtuse or rounded at each end, it is *oblong* (*fig.* 138). If such a leaf is more or less rounded at the base and its lower half is broadest, so that the whole is of the shape of an egg cut lengthwise, the leaf is *ovate* or *egg-shaped*, as in the Lilac

FIG. 131.

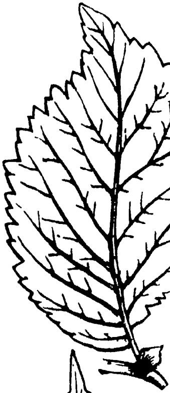


FIG. 132.

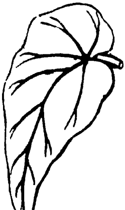


FIG. 133.

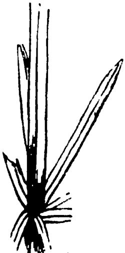
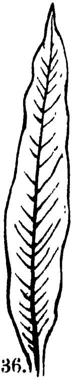


FIG. 134.



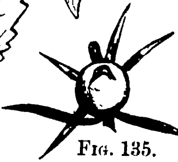


FIG. 135.

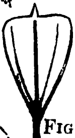
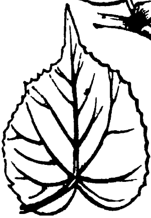
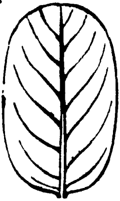
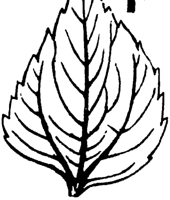


FIG. 136.







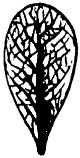


FIG. 137. FIG. 138. FIG. 139. FIG. 140.

Fig. 131. Leaf of Elm, with its margins biserrate, and the lamina unequal at its base.——*Fig.* 132. Unequal or oblique leaf of a species of *Begonia*. ——*Fig.* 133. Linear leaf of Goose-grass (*Galium Aparine*).——*Fig.* 134. Lanceolate leaf.——*Fig.* 135. Acerose or needle-shaped leaves of Juniper (*Juniperus communis*).——*Fig.* 136. A cuneate and mucronate-pointed leaf. ——*Fig.* 137. Cordate and acuminate leaf, with its margins dentate.——*Fig.* 138. Oblong leaf of Bladder-senna (*Colutea arborescens*).——*Fig.* 139. Ovate leaf, with its margins serrate.——*Fig.* 140. Obovate leaf.

(*fig.* 139); if of the same figure, but with the broad part towards the apex, it is *obovate* or *inversely egg-shaped* (*fig.* 140). When the lamina is broad at the apex, and abrupt-pointed, and tapers towards the base, as in some Saxifrages, the leaf is *cuneate* or *wedge-shaped* (*fig.* 136); if the apex is broad and rounded, and thence it tapers to the base, it is *spathulate*, as in the Daisy (*fig.* 141). When the lamina is broad and hollowed out at its base into two rounded lobes, and more or less pointed at the apex, the leaf is *cordate* or *heart-shaped*, as in the Black Bryony (*Tamus communis*) (*fig.* 137); if of the same shape, but with the apex broader than the base, and hollowed out into two rounded lobes, it is *obcordate* or *inversely heart-shaped* (*fig.* 144). When a leaf resembles a cordate one generally in shape, but has the apex rounded, and the whole blade usually shorter and broader, it is *reniform* or *kidney-shaped*, as in the Asarabacca (*Asarum europæum*) (*fig.* 143); when a leaf is reniform, but with the lobes at the base of the lamina pointed, so that it resembles the form of a crescent, it is *lunate* or *crescent-shaped*, as in *Passiflora lunata* (*fig.* 145). When the blade is broad and hollowed out at its base into two acute lobes, while it is pointed at the apex, so that it resembles the head of an arrow, the leaf is *sagittate* or *arrow-shaped*, as in the Arrowhead (*Sagittaria sagittifolia*) (*fig.* 146); when the lobes of such a leaf are at right angles to its axis, instead of passing downwards, it is *hastate* or *halbert-shaped*, as in Sheep's Sorrel (*Rumex Acetosella*) (*fig.* 147); when the lobes are entirely separated from the rest of the blade, as in the upper leaves of the Woody Nightshade (*Solanum Dulcamara*), it is *auriculate* or *hastate-auricled* (*fig.* 148).

FIG. 141.

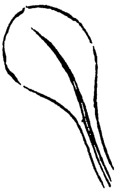


FIG. 142.

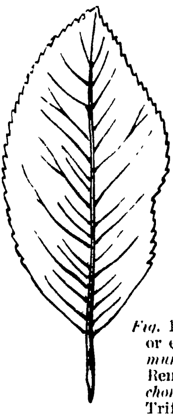


FIG. 143.

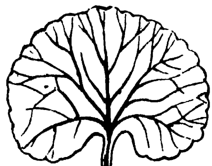


FIG. 144.

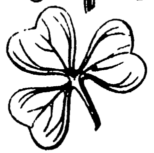


Fig. 141. Spathulate leaf.——*Fig.* 142. Oval or elliptical leaf of Pear-tree (*Pyrus communis*), with serrate margins.——*Fig.* 143. Reniform leaf of Ground Ivy (*Nepeta Glechoma*), with crenate margins.——*Fig.* 144. Trifoliate leaf with obcordate leaflets.

It frequently happens that a leaf does not distinctly present any of the above-described figures, but exhibits a combination of two of them, in which case we use such terms as *ovate-lanceolate*, *linear-lanceolate*, *cordate-ovate*, *cordate-lanceolate*, *elliptico-lanceolate*, *roundish-ovate*, &c., the application of which is at once evident.

In many cases we find leaves of different figures on the same plant, which is then said to be *heterophyllous*. In the Hairbell (*Campanula rotundifolia*), the radical leaves are *cordate* or *reniform*, and the cauline leaves *linear* ; and this difference of outline between the radical and stem leaves is by no means uncommon. In aquatic plants, again, where some of the leaves are submerged, while others float on the water, or rise above it into the air, as in the

FIG. 145.

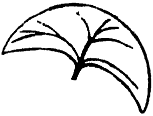
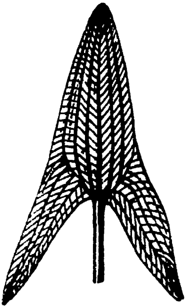


FIG. 146.



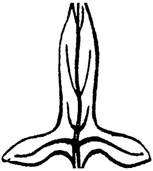


FIG. 148.

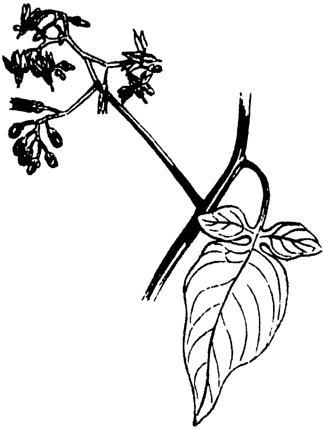


FIG. 149.

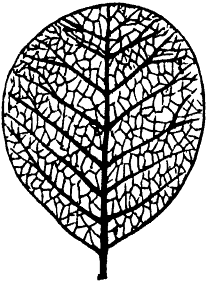


Fig. 145. Lunate or crescent-shaped leaf.——*Fig.* 146. Sagittate leaf.——*Fig.* 147. Hastate leaf.——*Fig.* 148. A portion of the stem of the Woody Nightshade (*Solanum Dulcamara*), bearing flowering stalk and an auriculate leaf.——*Fig.* 149. A sub-rotund or rounded leaf, with entire margins.

Water Crowfoot (*Ranunculus aquatilis*) and Arrowhead (*Sagittaria sagittifolia*), the leaves thus differently situated frequently vary in shape.

5. *Form.*—By this term we understand the solid configuration of the lamina. The terms used in defining the various forms are therefore especially applicable to thick or succulent leaves. Such leaves either assume some regular geometrical forms, as *cylindrical, pyramidal, conical, prismatic,* &c., and receive corresponding names; or they approach in form to some well-known object, and are hence termed *acicular, ensiform,* &c. Various other singular forms are also found, some of which will be subsequently alluded to.

Besides the above-described modifications which the blades of leaves present in reference to their *Margins, Incision, Apex, Outline,* and *Form,* they also present numerous other variations as regards their *surface, texture, colour,* &c.

Compound Leaves.

We have already defined a compound leaf. Its separate leaflets are subject to the same modifications of their margins, incision, apex, outline, form, texture, surface, colour, &c., as the blade of simple leaves, and the same terms are accordingly used in describing them. We have therefore only now to speak of the compound leaf as a whole, and the terms which are employed in describing its special modifications. We divide compound leaves into two types: the *Pinnate* and the *Palmate* or *Digitate.*

1. *Pinnate Compound Leaves.*—When a leaf of this type presents the appearance of several distinct portions or leaflets, it is termed *pinnate* (*figs.* 93, 94, 150); and the leaflets are then termed *pinnæ.* The leaflets are arranged in pairs in an opposite manner along the sides of the rachis or primary axis, and according to their number the leaf is said to be one-, two-, three-, or many-paired. Several kinds of pinnate leaves have also been distinguished by special names. When the main axis of a pinnate leaf is only winged at the extreme apex, thus appearing to bear a terminal leaflet (*fig.* 93), as in the Rose and Elder, it is *imparipinnate* or *unequally pinnate,* or *pinnate with an odd leaflet;* it is *equally* or *abruptly pinnate,* or *paripinnate,* when the main axis of the epipodium is not winged at all, but bears a number of secondary axes which are winged (*fig.* 94), as in some species of *Cassia,* the Mastich plant (*Pistacia Lentiscus*), Logwood (*Hæmatoxylon campechianum*), and *Orobus tuberosus*; and it is *interruptedly pinnate* (*fig.* 150) when the leaflets or secondary winged axes are of different sizes, so that small pinnæ are regularly or irregularly intermixed with larger ones, as in the Potato (*Solanum tuberosum*) and Silver Weed (*Potentilla anserina*). When the wing of the main axis is the largest and those

of the secondary axes are gradually smaller as they are nearer the base, it is *lyrately pinnate*, as in the common Turnip (*fig.* 151). This leaf and the true lyrate form often run into each other, so that it is by no means uncommon to find both varieties of leaf on the same plant, as in the common Turnip and Yellow Rocket.

When the leaflets of a pinnate leaf become themselves pinnate, or, in other words, when the partial axes which are arranged on the common one exhibit the characters of an ordinary pinnate leaf, it is said to be *bipinnate* (*fig.* 152); the leaflets borne by the partial or secondary axes are then commonly termed *pinnules*. When the pinnules of a bipinnate leaf become themselves pinnate, it is *tripinnate*, as in the Meadow Rue (*Thalictrum minus*) and the common Parsley (*fig.* 97); it commonly happens, however, that in these leaves the upper leaflets are less deeply divided, as in *fig.* 97. If the division extends beyond this, the leaf is *decompound*, as in many Umbelliferous plants (*fig.* 161).

FIG. 150.

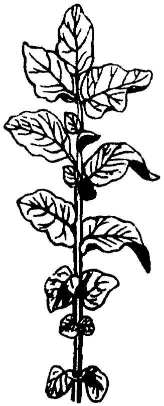


FIG. 151.

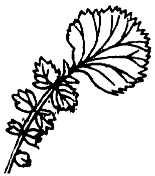


FIG. 152.

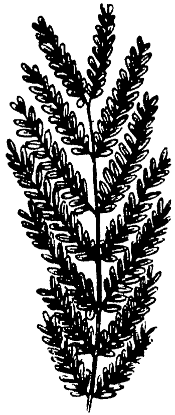


Fig. 150. Interruptedly pinnate leaf of the Potato.——*Fig.* 151. Lyrately pinnate leaf.——*Fig.* 152. Bipinnate leaf of a species of *Gleditschia*.

2. *Palmate Compound Leaves.*—Such a leaf is formed when the epipodium divides into several equal or nearly equal branches, each of which is separately winged; and hence these leaves are readily distinguished from those of the pinnate kind by their leaflets coming off from the same point, instead of, as in them, along the sides of a common primary axis. We distinguish several kinds of such leaves; a leaf is said to be *binate*, *bifoliate*, or *unijugate*, if it

consists of only two leaflets springing from a common point, as in *Zygophyllum* (*fig.* 153); it is *ternate* or *trifoliate* if it consists of three leaflets arranged in a similar manner, as in the genus *Trifolium*, which receives its name from this circumstance (*figs.* 144 and 154); it is *quadrinate* or *quadrifoliate* if there are four leaflets (*fig.* 155); it is *quinate* or *quinquefoliate* if there are five (*fig.* 156),

Fig. 153.

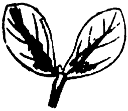


Fig. 154.

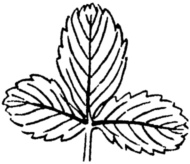


Fig. 155.

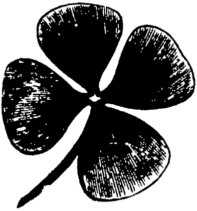


Fig. 156.

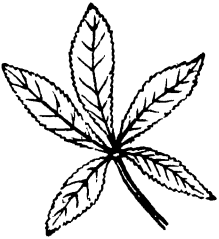


Fig. 157.

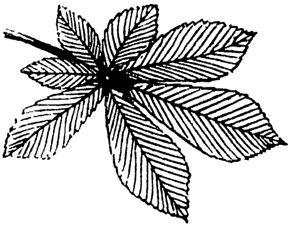


Fig. 158.

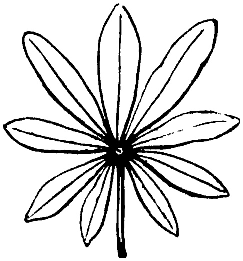


Fig. 159.

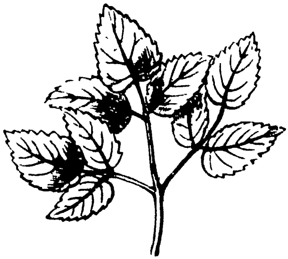


Fig. 153. A binate or bifoliate leaf.——*Fig.* 154. Ternate or trifoliate leaf. *Fig.* 155. Quadrifoliate leaf of *Marsilea quadrifolia*. ——*Fig.* 156. Quinate or quinquefoliate leaf.——*Fig.* 157. Septenate leaf of the Horse-chestnut (*Æsculus Hippocastanum*).——*Fig.* 158. Multifoliate leaf of a Lupin.——*Fig.* 159. A biternate leaf.

as in *Potentilla argentea* and *P. alba*; it is *septenate* or *septemfoliate* if there are seven, as in the Horse-chestnut and some Potentillas (*fig.* 157); and it is *multifoliate* if there are more than seven, as in many species of Lupin (*fig.* 158). The term *digitate* is generally used when the segments of such a leaf are long and narrow.

FIG. 160.

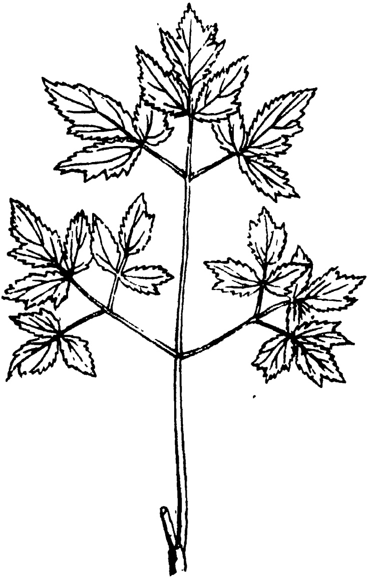


Fig. 160. Triternate leaf of Baneberry (*Actæa*).

2. INSERTION AND ARRANGEMENT OF LEAVES.

(1) INSERTION.—The point at which a leaf is attached to the stem or branch is called its *insertion*. Leaves are inserted on various parts of the stem and branches, and receive different names accordingly. The first leaves which are developed are called *cotyledons* (*fig.* 16, *c*, *c*). The cotylëdons are usually very different in their appearance from the ordinary leaves which succeed them. Leaves are called *radical* when they arise at, or below, the surface of the ground, and thus spring apparently from the root, but really from a shortened stem, or *crown of the*

root, as it is commonly called. Leaves are thus situated in what are termed acaulescent plants, such as the Dandelion and Primrose. The leaves which arise from the main stem are called *cauline*; those from the branches *ramal*.

(2) ARRANGEMENT OF LEAVES ON THE STEM, OR PHYLLOTAXIS. The term *phyllotaxis* is used in a general sense to indicate the various modes in which leaves are arranged on the stem or branches. The object of the arrangement in every case is to secure as far as possible that the laminæ of all shall be equally illuminated and that they do not shade each other. The successful discharge of their functions will be found to depend upon securing this. There are two main types of arrangement, in one of which a single leaf only is produced at a node, in the other two or more occur. In the former case the leaves are *scattered* or *alternate*; in the latter, they are said to be *whorled* (*fig.* 161). The leaves constituting a whorl are usually placed symmetrically round the stem, at equal distances laterally from each other. When there are only two leaves in each whorl, they are said to be *opposite*. When leaves are opposite, those of each pair are usually placed under the interval or space between the leaves of the pair above it. Those of the third pair are then vertically under those of the first. They are said to *decussate* (*fig.* 162), and the arrangement is called *decussation*. When whorls consisting of large numbers of leaves succeed each other, it also frequently happens that a similar arrangement occurs, so that the leaves of one whorl stand above the intervals of the whorl below it.

FIG. 161.

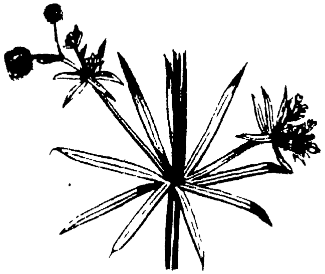


FIG. 162.

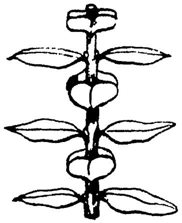


Fig. 161. Whorled leaves of a species of *Galium*. —*Fig.* 162. Decussate leaves of *Pimelea decussata*.

It sometime happens that, by the non-development of the internodes of an axillary branch, all the leaves of that branch are brought close together, in which case they form a *tuft* or *fascicle* (*fig.* 163), and the leaves are said to be *tufted* or *fascicled*. Such an arrangement is well seen in the Barberry and Larch. That the fascicle is thus produced is rendered evident by the fact that in the young branches of the Larch the internodes afterwards become elongated and the leaves are then separated from each other.

1. *Alternate Leaves.*—Though this arrangement is often termed *scattered*, it does not follow that there is necessarily any irregularity in the position of the leaves. Indeed, it would be better to term the arrangement *spiral*, as each leaf can be ascertained to be placed upon an imaginary spiral line winding symmetrically round the stem, and to be at a distance from the next leaf upon the spiral which may be expressed by a fraction of the circumference of the stem. This distance, which is usually constant, is known as the *divergence* of the leaves. The spiral can be traced and the divergence ascertained by counting from any particular leaf to the first one vertically above it. If we take a branch of the Apple or Cherry tree (*fig.* 164), and, *commencing with any particular leaf* which we will mark 1, *proceed upwards, taking the successive* leaves in the order of their ages and joining their bases by a line or piece of string, we shall find that after passing the leaves marked 2, 3, 4, and 5, we shall reach the one marked 6, which will be found to be situated vertically over the 1st; and then proceeding further, that the 7th is directly over the 2nd, the 8th over the 3rd, the 9th over

FIG. 163.

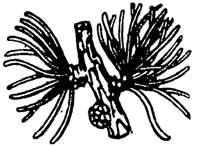


FIG. 164.

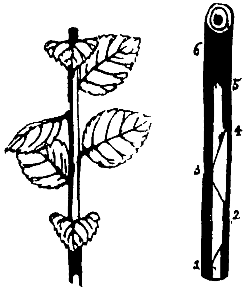


Fig. 163. Fascicled or tufted leaves of the Larch.——*Fig.* 164. A portion of a branch of the Cherry-tree with six leaves, the sixth of which is placed vertically over the first. The right-hand figure is the same branch magnified, the leaves having been removed, and numbers placed to indicate the points of their insertion.

the 4th, the 10th over the 5th, and the 11th over the 6th and 1st; a vertical line drawn down the stem through the base of any leaf will therefore pass through the base of every fifth leaf above and below it. These lines that can be drawn vertically down the stem through the leaf-bases are known as *orthostichies*, and the imaginary spiral line is called the *genetic spiral*. If we refer again to the arrangement of the leaves in the Cherry or Apple (*fig.* 164), we shall find that before we arrive at the sixth leaf, which is over the first, the string or line used to connect the bases of the leaves will have passed twice round the circumference of the branch. The point where a leaf is thus found, which is placed perpendicularly over the first, shows the completion of a *series* or *cycle*, and thus in the Cherry and Apple the cycle consists of five leaves. As the five leaves are equidistant from each other, and as the line which connects them passes twice round the stem, the distance of one leaf from the other will be ⅖ of its circumference. The fraction ⅖ expresses the *angular divergence*, or the length of the arc interposed between the insertion of two successive leaves. If a circle be drawn to represent the circumference of the stem, and the position of the orthostichies which bear two consecutive leaves be marked upon it, and radii be drawn from them to the centre of the circle, the angle so formed will show the divergence, and will be ⅖ of 360°, or 144°. The successive leaves as they are produced on the stem, as we have seen, are also arranged in similar cycles. This arrangement in cycles of five is common in Dicotyledons. It is termed the *pentastichous* or *five-ranked arrangement*.

A second variety of arrangement in alternate leaves is that which is called the *distichous*, or *two-ranked*. Here the second leaf on the spiral is on the opposite side of the stem to the first (*fig.* 165), and the third, being on the opposite side to the second, is placed vertically over the first, and thus completes the cycle, which consists of only two leaves; the fourth leaf is over the second, and the fifth over the third and first, thus completing a second cycle; and so on with the successive leaves. Here one turn completes the spiral, so that the distance between the leaves is ½ the circumference of a circle, and the angular divergence is 180°. This arrangement is the normal one in all Grasses, and many other Monocotyledons; the Lime-tree (*fig.* 165) and other Dicotyledons exhibit a similar arrangement.

A third variety of arrangement in alternate leaves is the *tristichous* or *three-ranked* (*fig.* 166). In this variety, if we start with any leaf and mark it No. 1, and then pass to 2, 3, and 4, we shall find that we shall make one turn round the stem before coming to a leaf vertically over the first, which will be the fourth in order, and thus complete a cycle composed of three leaves. In like manner, the fifth leaf will be over the second, the sixth over the third, and the seventh over the fourth and first, thus completing a second cycle; and so on with the succeeding leaves. Here the angular divergence is $\frac{1}{3}$ of 360°, or 120°. This arrangement is by far the most common one among Monocotyledons.

A fourth variety of phyllotaxis in alternate leaves is the *octostichous* or *eight-ranked.* Examples of this variety are afforded by the Holly and Aconite. In this the ninth leaf is over the first, the tenth over the second, the eleventh over the third, and so on; thus eight leaves will complete the cycle; and, as the spiral line in this distance makes three turns round the stem, the angular divergence will be measured by $\frac{3}{8}$ of the circumference: that is, it will be $\frac{3}{8}$ of 360°, or 135°.

FIG. 165.

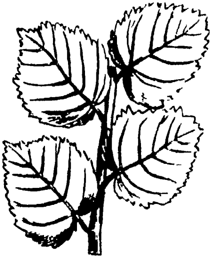


FIG. 166.

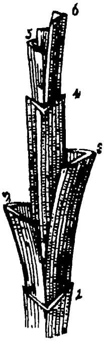


Fig. 165. Portion of a branch of the Lime-tree, with four leaves arranged in a distichous or two-ranked manner.——*Fig.* 166. Portion of a branch with the base of the leaves of a species of *Carex*, showing the tristichous or three-ranked arrangement. The numbers indicate the successive bases of the leaves.

We can arrange the fractions representing these divergences in a series thus: $\frac{1}{2}$, $\frac{1}{3}$, $\frac{2}{5}$, $\frac{3}{8}$, and we see that a certain relation exists between them; for the numerator of each fraction after the second is equal to the sum of the numerators of the two preceding fractions, and the denominator to the sum of their denominators. We may continue the series in the same way, when we get the fractions $\frac{5}{13}$, $\frac{8}{21}$, &c., and we find that instances of the occurrence of these more complex divergences are met with. Other similar series exist; we can meet with cases which taken together form the series $\frac{1}{4}$, $\frac{1}{5}$, $\frac{2}{9}$, $\frac{3}{14}$, &c., and others again which may be arranged in the order $\frac{1}{2}$, $\frac{2}{3}$, $\frac{3}{5}$, $\frac{5}{8}$, $\frac{8}{13}$, &c.

In computing these fractions we have assumed that the genetic spiral is uniform in its direction all along the axis. It may pass either from right to left or in the opposite direction. Occasionally cases are found, however, where the direction of its torsion is reversed at the conclusion of each complete cycle. Sometimes, again, the spiral changes as the axis gets older, the earliest leaves, or perhaps the youngest, being of a different order from the rest. Sometimes by the suppression of the internodes of a spiral cycle the leaves are apparently whorled or opposite. Such a cycle consequently forms a *pseudo-whorl.*

FIG. 167.

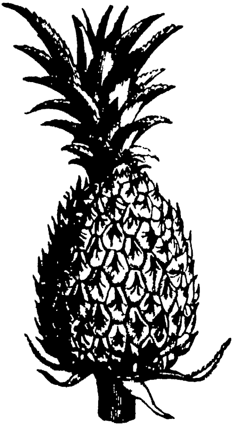


FIG. 168.

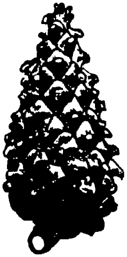


Fig. 167. Pineapple fruit (*Sorosis*), surmounted by a crown of empty bracts. *Fig.* 168. Cone of the Scotch Fir. Both show a spiral arrangement of the leaves.

The laws of phyllotaxis are frequently interfered with by accidental causes which produce corresponding interruptions of growth; it is then difficult, or altogether impossible, to discover the regular condition. In the case of axes whose internodes are much elongated, the arrangement is sometimes apparently altered by torsion of the stem or branch. This may also be seen with short internodes, though less frequently. The direction of the torsion of the axis may be uniform, or may change in different regions of it.

In *Pandanus* there are usually three orthostichies which pass straight down the stem, but sometimes a torsion of the latter makes them spiral instead of straight. A singular case of torsion is seen in *Baptisia perfoliata*, whose leaves, which are normally in two ranks, become in the upper part of the stem arranged in a single rank, owing to a twist of the successive internodes, first to the right and then to the left.

All the above varieties of phyllotaxis in which the angular divergence is such that the orthostichies are vertical, and the leaves completing the cycles are thus directly over those commencing them, are called *rectiserial*; while those in which the divergence is such that the orthostichies themselves are slightly twisted spirally are termed *curviserial*. The fraction expressing the angular divergence in any case can be easily ascertained. Its denominator is the number of leaves in a cycle; its numerator is the number of times the genetic spiral passes round the stem in tracing the cycle.

We see thus that when leaves are alternate the successive leaves form a spiral round the axis. In the majority of cases, its direction in both stem and branches is the same, and it is then said to be *homodromous*; but instances also occasionally occur in which its direction is not the same in both, when it is called *heterodromous*.

2. *Opposite and Whorled Leaves.*—We have already observed, with regard to these modifications of arrangement, that each successive pair, or whorl, of leaves, as they succeed each other, is not commonly inserted immediately over the preceding one, but that the second pair, or whorl, is placed over the intervals between the leaves of the first, the third over those between the leaves of the second, and so on (*fig.* 162). Here, therefore, the third pair of leaves will be vertically over the first, the fourth over the second, the fifth over the third, and so on. This arrangement occurs in plants belonging to the *Labiatæ* and *Oleaceæ*, and is called *decussation*, as previously noticed. In some cases the successive pairs or whorls are not placed directly over the intervals between the leaves of those below them, but a little on one side, so that we have to pass to some higher pair or whorl than the third before we arrive at one which is placed directly over the first. Such arrangements, therefore, suggest that the successive pairs and whorls of leaves are arranged in a spiral manner with regard to each other. Opposite leaves may

thus be regarded as due to two spirals proceeding up the stem simultaneously in two opposite directions; and the whorl as due to as many spirals as there are component leaves.

Cases in which the decussation of the whorls is not exact may sometimes be explained by torsion of the axis.

The constituent leaves of a whorl are usually of the same age, but not always so. In the *Characeæ* the members of the whorl are developed in a definite sequence. Spurious whorls or *pseudo-whorls* may arise in certain cases where in the bud one leaf develops from each of many nodes, which at that time are close together. By non-development of some of the internodes, many of these leaves continue in close proximity, and such clusters being separated by growth of a particular internode between them, the originally spiral arrangement is lost and a whorled one apparently takes its place. The members of each pseudo-whorl are, of course, of different ages.

The alternation or opposition of leaves is generally constant in the same species, and even in some cases throughout complete Natural Orders. The plants of the *Boraginaceæ* have alternate leaves; those of the *Caryophyllaceæ*, opposite; those of the *Labiatæ*, opposite and decussate; those of the *Leguminosæ*, alternate; those of the *Rosaceæ*, alternate, &c. While the opposition or alternation of leaves may thus be shown to be constant throughout some complete Natural Orders, yet a change from one arrangement to another may sometimes be seen upon the same stem, as in the common Myrtle and Snapdragon. Many plants which have opposite leaves on their adult parts often exhibit an alternate arrangement at the extremities of their young branches when these grow very rapidly. In other cases leaves normally arranged alternately become opposite, or whorled, through the non-development of the successive internodes by interruptions of growth; in others again the whole of the internodes of a branch remain undeveloped, the leaves then being tufted or fascicled as already noticed (*fig.* 163). Generally, however, the relative position of leaves is so constant in any particular species that it forms one of its characteristic distinctions.

A certain order of arrangement may often be noticed between the leaves of a stem and those of the branches springing from their axils. In Dicotyledons which have opposite leaves, the leaves of the pair first produced upon a branch usually decussate with the leaf at its base. In Monocotyledons the first leaf is placed upon the side of the branch nearest to the stem, opposite to the leaf from whose axil it arises.

(3) ARRANGEMENT OF THE LEAVES IN THE BUD.—We proceed now to examine what is known as *vernation*, or the different modes in which the leaves are disposed while in an unexpanded condition in the bud. We may consider, 1st, the modes in which each of the leaves, considered independently of the others, is disposed; and 2nd, the relation of the several leaves of the same bud, taken as a whole, to one another. The arrangements of the separate leaves may be divided into:—1st, those in which the leaf is simply *bent* or *folded*; 2nd, those in which it is *rolled*. Of the first modification we have three varieties:—1st, the upper half of the leaf may be bent upon the lower, so that the apex approaches the base, as in the Tulip-tree; it is then said to be *reclinate* or *inflexed* (*fig.* 169); 2nd, the right half may be folded upon the left, as if the ends and midrib or axis of the leaf formed a hinge, as in the Oak and Magnolia, when it is called *conduplicate* (*fig.* 170); 3rd, each leaf may be folded up a number of times like a fan, as in the Sycamore, Currant, and Vine, when it is *plaited* or *plicate* (*fig.* 171). Of the second modification we have four varieties:—1st, the apex may be rolled up on the axis of the leaf towards the base, like a crosier, as in the Sundew and Ferns, when it is *circinate* (*fig.* 172); 2nd, the whole leaf may be rolled up from one margin into a single coil, with the other margin exterior, as in the Apricot and Banana, in which case it is *convolute* (*fig.* 173); 3rd, the two

FIG. 169.

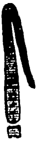


FIG. 170.

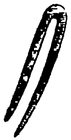


FIG. 171.

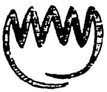


FIG. 172.

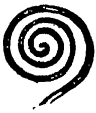


FIG. 173.

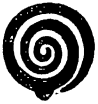


FIG. 174.

FIG. 175.

Fig. 169. Vertical section of a reclinate leaf.——*Fig.* 170. Transverse section of a conduplicate leaf.——*Fig.* 171. Transverse section of a plaited or plicate leaf.——*Fig.* 172. Vertical section of a circinate leaf.——*Fig.* 173. Transverse section of a convolute leaf.——*Fig.* 174. Transverse section of a revolute leaf.——*Fig.* 175. Transverse section of an involute leaf.

margins of the leaf may both be rolled inwards on the upper surface of the leaf towards the midrib, which remains immovable, as in the Violet and Water-lily, when it is *involute* (*fig.* 175); 4th, the two margins may be rolled outwards or towards the midrib on the lower surface of the leaf, as in the Dock and Azalea, in which case it is *revolute* (*fig.* 174).

We pass now to consider, *secondly*, the relation of the several leaves of the same bud, taken as a whole, to one another. Of this we have several varieties which may also be treated of in two divisions:—1st, those in which the component leaves are *flat* or *slightly convex*; and 2nd, where they are *bent* or *rolled*.

FIG. 176.

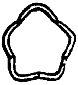


FIG. 177.

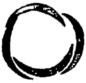


FIG. 178.

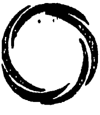


FIG. 179.

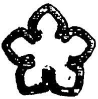


FIG. 180. FIG. 181.

FIG. 182.

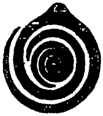


Fig. 176. Transverse section of a bud to show the leaves arranged in a valvate manner.——*Fig.* 177. Transverse section of a bud to show imbricate vernation.——*Fig.* 178. Transverse section of a bud to show twisted or spiral vernation.——*Fig.* 179. Transverse section of a bud to show induplicate vernation.——*Fig.* 180. Transverse section of a bud showing equitant vernation.——*Fig.* 181. Transverse section of a bud showing obvolute vernation.——*Fig.* 182. Transverse section of a bud showing supervolute vernation.

Of the first division we may recognise three varieties:—1st, that in which the leaves are placed nearly in a circle or at the same level, and in contact by their margins only, without overlapping each other, when they are *valvate* (*fig.* 176); 2nd, that in which the leaves are placed at different levels, and the outer successively overlap the inner to a greater or less extent by their margins, as in the Lilac, and in the outer scales of the Sycamore, when they are said to be *imbricate* (*fig.* 177); and 3rd, when leaves are placed as in imbricate vernation, and one margin of each leaf overlaps that of another, while the other margin, in its turn, is overlapped by a third, the vernation is *twisted* or *spiral* (*fig.* 178). A variety of the valvate arrangement is the *induplicate* form, in which the edges of the leaves, instead of merely touching, are bent inwards for some little distance (*fig.* 179). Of the second division, that is where the component leaves of the bud are *bent* or *rolled*, we have three varieties:—1st, when the leaves are conduplicate, and each completely infolds all those younger than itself, so that in transverse section they seem to sit astride of them, as in the Privet, they are *equitant* (*fig.* 180); 2nd, when the half of one conduplicate leaf receives in its fold the half of another folded in the same manner, as in the Sage, the vernation is *half-equitant* or *obvolute* (*fig.* 181); and 3rd, when a convolute leaf encloses another which is rolled up in a like manner, as in the Apricot, the vernation is *supervolute* (*fig.* 182).

The terms thus used in describing the different kinds of vernation are also applied to the component parts of the flower-bud, under the name of *æstivation* or *præfloration*, though the arrangements of the latter are more complex. When speaking of the flower-bud, we shall have therefore to refer to some of them again, together with others not found in the leaf-bud.

FIG. 183.

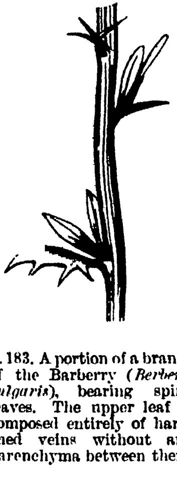


Fig. 183. A portion of a branch of the Barberry (*Berberis vulgaris*), bearing spiny leaves. The upper leaf is composed entirely of hardened veins without any parenchyma between them.

3. OTHER MODIFICATIONS OF THE LEAF.

Besides the kinds of leaf which we have now examined, there occur others which serve various purposes, and are frequently adaptations to special habits of life; such are *spinous leaves*, *leaf-tendrils*, and *pitchers*. Either the whole leaf or part of it may undergo modification of this kind. We have again the various forms of *scaly* or *cataphyllary* leaves, and the leaves specially connected with reproductive structures, including the sporophylls and other leaves of the flower and inflorescence.

Leaf-spines.—Any part of the leaf may exhibit a spiny character. In the Holly (*fig.* 122) and many Thistles (*fig.* 93), the veins project beyond the blade, and become hard and spiny; while in the Barberry (*fig.* 183) the whole lamina becomes spinous. The whole epipodium assumes a spiny character in some species of *Astragalus* also. The stipules sometimes become transformed into spines, as in *Robinia pseud-acacia* (*fig.* 93).

Spines of leaves may be readily distinguished from the thorns already described, which are modified branches, because the latter always arise from the axil of the leaf, instead of from the leaf itself. Spines may be readily distinguished from *prickles* by their internal structure.

Leaf-tendrils.—Various parts of the leaf may become transformed into tendrils, the organs sensitive to contact, which have already been described in connection with the modifications of the stem. Their purpose is to enable a weak-stemmed plant to climb up any support with which they come in contact, and round which they can twine. Such tendrils may be a prolongation of the leaf-blade beyond the apex, as in *Gloriosa superba*, the leaflets of a compound leaf in many of the *Leguminosæ* (*figs.* 82 and 184), the whole petiole in *Lathyrus Aphaca* (*fig.* 185), and the stipules in *Smilax* (*fig.* 186).

FIG. 184. FIG. 186.

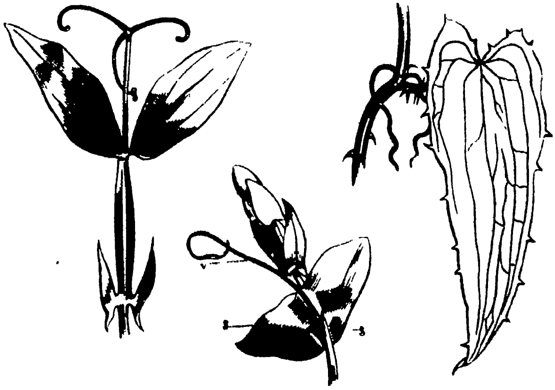


FIG. 185.

Fig. 184. Leaf of a species of *Lathyrus*, showing a winged petiole, with two half-sagittate stipules at its base, and terminated by a tendril.——*Fig.* 185. A portion of the stem of *Lathyrus Aphaca*, with stipules, *s*, *s*, and cirrhose phyllopodium, *v*.——*Fig.* 186. A portion of the stem of *Smilax*, bearing a petiolate leaf, and two tendrils in place of stipules.

Ascidia or Pitchers.—These are the most remarkable of all the anomalous forms presented by leaves. They may be seen in the species of *Nepenthes* or Pitcher-plants (*fig.* 187), in the species of *Sarracenia* or Side-saddle plants (*fig.* 188), and in many others. In *Sarracenia* (*fig.* 188), the pitcher appears to originate much as does the peltate leaf; by further basal growth it becomes tubular. In *Nepenthes* (*fig.* 187), the petiole is winged for a certain distance, then assumes the appearance of a tendril, and ultimately bears a pitcher, *p*; this is arched over by a lid, *l*, which is united to it by an articulation.

Equitant Leaves.—A peculiar form of leaf is seen in *Iris*, *Phormium*, and certain other Monocotyledonous plants. The leaf is long and comparatively narrow, and its flattened surfaces are directed laterally like those of phyllodes. Its construction can be determined by an inspection of its base, where it is seen to be split partly up one edge, the split embracing the next leaf. The blade is, in fact, folded along its centre, and the upper surfaces of the folds are united together along nearly the whole of the lamina. One edge of the blade so corresponds to the conjoined margins of the leaf, the other to its central line, and the two sides to the whole dorsal surface. The upper surface is only exposed at the sheathing base.

FIG. 187.

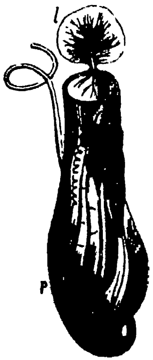


FIG. 188.

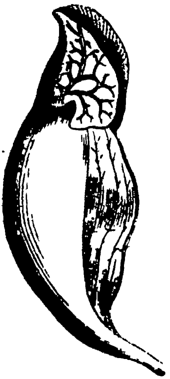


FIG. 189.

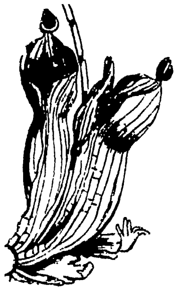


Fig. 187. Pitcher of a species of Pitcher-plant (*Nepenthes distillatoria*). *p*. Pitcher covered by the lid, *l*.——*Fig.* 188. Pitcher of the Side-saddle plant (*Sarracenia purpurea*).——*Fig.* 189. Pitchers of *Heliamphora*.

Scaly or Cataphyllary Leaves.—These are of very simple structure; they occur as coverings to buds and thin membranous coatings to tunicated bulbs and corms. The fleshy leaves which form the bulk of tunicated or scaly bulbs may be included here. They do not contain chlorophyll, and are usually storehouses of nutritive materials In some parasitic and saprophytic plants, such as the Broom-rapes, and certain Orchids, fleshy scales replace the ordinary foliage leaves.

Floral Leaves.—These include the various forms which occur in connection with the mechanisms of spore production. They will be discussed later in more detail. They show much peculiarity of form, colour, and arrangement.

CHAPTER II.

MORPHOLOGY OF THE REPRODUCTIVE ORGANS.

THE life of an individual being but limited in its duration, we find various mechanisms developed to continue the existence of the species; these form the Reproductive Organs. We have seen that new individuals are produced from existing ones by various methods, which may be grouped into three classes, known respectively as the *vegetative*, the *asexual*, and the *sexual*.

Instances have already been given of the origination of special adventitious buds upon various parts of plants which, becoming detached from the parent form, can carry on independent existence. Such are the young plants arising on the stolons or runners of the Strawberry, or on the leaves of *Bryophyllum*: all such belong to the first group. We have also found that plants produce from time to time special cells which fall away from the parent and are by themselves capable of giving rise to new plants. When these asexual cells occur upon the sporophyte they are termed *spores*; when they arise upon the gametophyte, as they do in the Algæ and Fungi, they are called *gonidia*. We have noted, further, that in other cases special cells are produced which unite in pairs to form new cells, from which again the new phase or form of the plant is developed: these are sexual cells or *gametes*. The two forms or phases are named *sporophytes* and *gametophytes*, on account of their bearing spores and gametes respectively. The gametophyte, besides bearing its gametes, may, as just mentioned, also bear asexual cells or gonidia, indistinguishable in their structure and behaviour from the spores of the sporophyte. The sporophyte, however, never gives rise to gametes.

On germination the asexual cells, whether spores or gonidia, give rise to gametophytes; in all forms above the Thallophytes the cell (known as a *zygote*) resulting from the fusion of the gametes develops into a sporophyte. In some Thallophytes the zygote gives rise to a rudimentary sporophyte; in others to a gametophyte.

We may now examine separately the vegetative, asexual, and sexual reproductive mechanisms.

SECTION I.

VEGETATIVE REPRODUCTIVE STRUCTURES.

Vegetative reproduction is the simplest manner of producing a new individual, and can in the lower forms often hardly be distinguished from ordinary growth. It can be illustrated by a series of examples. In the lowest Fungi and Algæ, in which the plant consists only of a single cell, as in Yeast, an outgrowth from the cells appears, which becomes detached and forms a new individual, giving rise to others in turn. Sometimes the process is so rapid that the new cell gives rise to another before being detached, and this may go on till a chain of cells is formed. Each of these is, however, an independent Yeast plant, and the separation is a mere matter of time. This process is known as *budding*. In other cases, as in the Desmids, the cell divides into two, each of which, by subsequent growth, becomes a new individual. This is only slightly different from the first process, and is known as *fission*.

In more highly differentiated plants certain portions of the parent are detached, which develop into the adult forms. These are generally known as *gemmæ*, and may be unicellular or multicellular. Instances are found of the former among the Fungi; of the latter in higher groups also, particularly the Liverworts and Mosses, where they are developed in special places. In the former group they are found in cup-like receptacles upon the upper surface of the thalloid stem; in the latter their position varies greatly. In the Lichens small portions of the thallus are set free; these are known as *soredia*. They have the same structure as the thallus itself.

In many plants branches frequently become independent by the perishing of the main axis on which they originate. In the case of the runner of the Strawberry a bud is developed on the stem which puts out roots and attaches itself to the ground. Then the stem on which it arises perishes, and the new plant lives for itself. Other cases of similar behaviour are furnished by the production of bulbs or corms in many plants, and in the behaviour of many rhizomes.

Cuttings illustrate the same mode of reproduction. A piece of the stem, with buds and leaves, when separated from the parent and planted in soil, will, under appropriate conditions, put out roots from the cut surface, and thus replace the parts missing, and lead an independent life. Buds may arise from wounded leaves or petioles under similar conditions.

In this mode of reproduction the form of the plant from which the new one is derived remains unchanged. Thus sporophyte gives rise to sporophyte, gametophyte to gametophyte, and there is no alternation of generations.

SECTION II.

ASEXUAL REPRODUCTIVE ORGANS.

The Spores.

The relative dimensions of the sporophyte and gametophyte in the different classes of plants vary considerably. There is, however, a somewhat regular series in both. The morphology of the gametophyte will be treated of in a subsequent chapter. The sporophyte can be distinguished only with difficulty in the Algæ and Fungi, and many of these plants do not possess one; in the Mosses the sporophyte is the *theca*, *capsule*, or *sporogonium*, which is developed from a fertilised cell or *zygote* at the apex of the leafy shoot. In the Ferns the sporophyte is the so-called *plant*, as it is in the Equisetums and Club-mosses. The Phanerogams show the sporophyte in its best development, the plant as we see it representing that phase.

The reproductive organs of the sporophyte are specialised cells known as *spores*. These are generally single cells, usually furnished with a tough, sometimes much-thickened coat, enclosing, in addition to its living substance or protoplasm, various nutritive materials, such as starch, sugar, oil, &c. The spore-coat in some cases is thin and delicate. Spores are produced in various ways in different plants, but are usually found in special receptacles known as *sporangia*.

As we have already said, similar asexual cells are very generally borne upon the gametophytes of the Algæ and Fungi. These are known as *gonidia*, and the structures in or on which they arise may be called *gonidangia*.

In the cases where the spore has no outer wall, it must be regarded as a naked piece of protoplasm. It is then frequently furnished with a number of vibratile threads at one or more points of its surface, by which it can move freely about in water. Such a spore is known as a *zoospore*. It only occurs in the lowest forms of plants, the Algæ and Fungi.

The asexual cells, or gonidia, which are borne upon the gametophytes of the Algæ and Fungi, have the same structure as spores.

In the Vascular Cryptogams the sporophyte of some plants produces one kind of spore only; that of others gives origin to two kinds, which differ from each other in size and in the form of gametophyte to which they give origin. They are known as *microspores* and *macrospores* or *megaspores* respectively. According to whether one or two kinds of spore are produced, the sporophyte is called *homosporous* or *heterosporous*. The Phanerogams are all heterosporous, and special terms are employed to characterise their microspores and megaspores respectively. The former are known as *pollen-grains*, and the latter as *embryo-sacs*. These terms were employed before the true nature of these structures was known; it is convenient to use them still, recognising, however, their true morphological nature.

The Sporangia.

A good deal of variety is found in the form of the organ on or in which the spores or the gonidia originate. In unicellular plants the whole cell may become a sporangium or gonidangium, as it sometimes does in Yeast, where its contents divide into four parts, each of which becomes surrounded by a cell-wall, and the four spores so formed become liberated by the disintegration of the original cell-wall. In many Fungi there is no special gonidangium, but the gonidia are abstricted from certain special cells of the filament or the surface of the thallus, and frequently form long chains which eventually separate into distinct gonidia. In others the gonidia are solitary at the end of a filament. Some botanists regard these as gonidangia, each producing a single gonidium.

In higher plants the sporangium is not a single cell, but a differentiated multicellular body.

In the group of the Bryophyta, or Moss-like plants, there are no definite sporangia, but the spores are produced in a special part of the sporophyte, known as the *capsule* or *sporogonium*. This must not be confused with a *sporangium*, as it contains other structures than spores; it is a highly complex body, and forms the greater part of of the sporophyte.

In all plants above the Mosses the sporangium is a well-differentiated roundish or ovoid structure, possessing a wall or coat, often furnished with particular cells to secure its opening when ripe. In the interior is a cavity, in which the spores usually lie free and present the structure already described.

The position of the sporangia varies also. Usually they arise on leaves, which are then known as *sporophylls*, each of which may bear one, two, four, or many. They may be on the back of the leaf, as in most Ferns; on its edges, as in the case of the megasporangia, or ovules, of most Phanerogams; or in its axil, as in many *Lycopodinæ*; or embedded in its substance, as in the *Ophioglossaceæ* and the anthers of the Phanerogams. The megasporangia of the Yew-tree among Gymnosperms, and those of certain Angiosperms, arise on the axis or stem, and not upon the leaves. The megasporangia are more frequently borne on the axis than are the microsporangia.

In many cases the sporangia are found in isolated groups, when each group constitutes a *sorus*, as in most Ferns. Sometimes the sporangia in a sorus are not isolated but coherent together, as in *Marattia*, and in the anthers of the Phanerogams.

When a plant bears both microspores and megaspores, sporangia producing each kind may be present in the same sorus; or a sorus may consist of either micro- or megasporangia. Generally, though not always, the sorus is covered and protected by an outgrowth of the surface of the plant, known as an *indusium*. The sorus is represented in the Phanerogams most clearly in the arrangement of the microsporangia of some Cycads, which are collected into groups on the surface of a modified leaf. A kind of indusium is present in the *Cupressineæ*, where the sporangia when young are covered by an outgrowth of the under surface of the sporophyll.

In other cases the sporangia are single and not grouped. Such sporangia then represent sori, and each may be covered by an indusium, as in the case of the megasporangium of *Azolla*. Some botanists hold that the coats or integuments which invest closely the megasporangium of the Phanerogams, generally called the *ovule*, represent this indusium.

When the spores are mature they are liberated by the bursting of the sporangium wall, and they give rise to their gametophytes after this liberation, the latter thus being free from the sporophyte. As already noted, however, an exception to this is found in the case of the megaspore of the Phanerogams, which germinates *in situ* in the sporangium (ovule).

The megasporangium of the Phanerogams shows considerable diversity of form in different plants. It will be convenient to reserve a discussion of its principal features till the end of the present chapter, where it will be treated of under its popular name *ovule.*

The Sporophore or Inflorescence.

In the sporophytes of all the higher plants, the sporangia, and the sporophylls on which they arise, are collected together to a greater or less extent, and thus give rise to peculiar modifications of the ordinary vegetative body. In the so-called Flowering Plants, or Phanerogams, ths sporophylls with their sporangia occur in special structures known as *flowers.* These in turn are usually arranged upon special branches, which form a branch system, sharply marked off from the remainder of the plant. This branch system constitutes what is generally called the *sporophore* or *inflorescence.* In many of the lower plants the inflorescence is not so conspicuously shown, the sporophylls often resembling the foliage leaves and not being collected into flowers. The term *flower* should not, however, be restricted to the so-called Flowering Plants, but may be applied to *any shoot especially adapted to spore-production.* The flower of the Phanerogams consists of an axis, generally bearing leaves, which may be of two kinds: the *sporophylls,* or those which carry the sporangia, and certain protective leaves which bear the name of the *perianth.* Sometimes the axis bears no leaves, and the sporangia are developed upon the axis itself, as in the case of the ovule of the Yew-tree. Usually in Phanerogams the flower includes two kinds of sporophylls: those bearing microsporangia, which are named *stamens*; and those carrying megasporangia, which are known as *carpels.* Many flowers, however, contain only one of the two, and are then known as *staminate* and *pistillate* respectively.

The sporophyll may present many forms: in most Ferns it can be distinguished from an ordinary foliage leaf only by the presence of the sporangia on its under surface; in the Equisetums, or Horsetails, it is a peltate scale; several spring together from the apex of the shoot, each bearing many sporangia between the scale and the axis; in most Gymnosperms the form varies from a structure similar to that of *Equisetum,* to a broad-based, scaly leaf, with the sporangia on either its dorsal or ventral surface, as in the staminate and pistillate flowers of *Pinus* respectively. In the Angiosperms the stamen is a club-shaped body with a swollen head; the carpel is more leaf-like, looking in its simplest form like a leaf folded upon its midrib, as if the latter were a hinge. Its upper surface so becomes internal, and its margins are united in front, forming a closed chamber, the *ovary*. Often when several carpels are situated side by side, instead of their two margins uniting together, the margins of each fuse with those of their contiguous neighbours, forming a single chamber.

In plants higher in the scale than the Ferns the sporophore

FIG. 190.

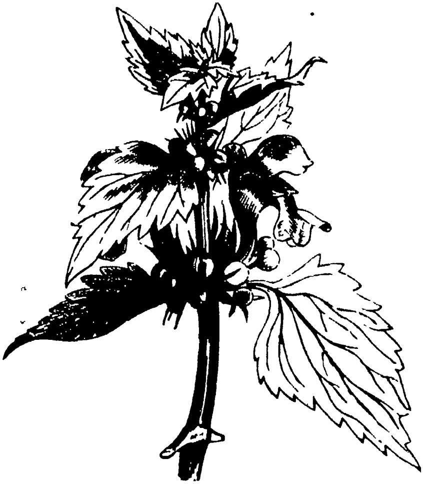


Fig. 190. Flowering stalk of the White Dead-nettle (*Lamium album*), with leafy bracts and verticillasters in their axils.

forms a distinct branch system, easily distinguishable from the vegetative one. In consequence of its ultimate shoots taking the form of flowers, it is known as the *inflorescence*. It shows a very great variety of form, depending on the mode of branching and the relative development of its several parts. These varieties must be treated of in some detail.

As in the case of the vegetative branch system, we have to discuss the axis and its ramifications, and the leaves which are borne upon it. The latter are all more or less specialised, but fall into two categories, the leaves of the flower or ultimate branch, and those of the axis apart from the flower, which are included under the general term *bract*, or *hypsophyll*. It will be convenient to examine the latter first.

1. THE BRACT.

The term *bract* is properly applied only to the leaf from the axil of which a solitary flower or a floral axis arises. All other leafy structures which are found upon such an axis in the cases in which it occurs, and which therefore come between the bract and the flower properly so called, should be termed *bractlets* or *bracteoles*. These two kinds of bracts are, however, not always distinguished in practice, the term *bract* being frequently used to designate either variety.

FIG. 191.

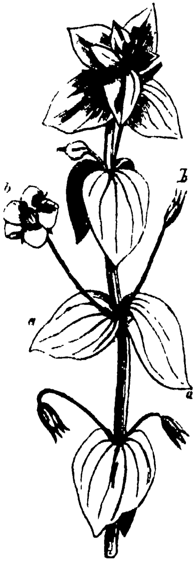


FIG. 192.

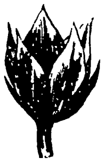


FIG. 193.

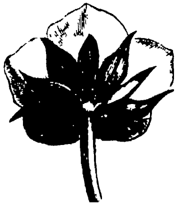


Fig. 191. Flowering stalk of the Pimpernel (*Anagallis arvensis*). *b*, *b*. Solitary flowers arising from the axil of the leafy bracts, *a*, *a*.— *Fig.* 192. Calyx of the Marsh-mallow (*Althæa officinalis*), surrounded by an epicalyx or involucre. —*Fig.* 193. Flower of the Strawberry (*Fragaria vesca*), surrounded by an epicalyx or involucre.

Bracts vary much in appearance and in dimensions. Some of them are of considerable size and green in colour, so that in most respects they are almost indistinguishable from the ordinary foliage leaves of the plant upon which they are placed, as in the White Dead-nettle (*fig.* 190), and in the Pimpernel (*fig.* 191, *a*, *a*). Such bracts can really often be distinguished from the foliage leaves only by their position with regard to the flower-stalk or flower. In most cases, however, bracts, although very commonly of a greenish colour, are smaller than the foliage leaves. In many plants they may be known from the ordinary leaves not only by their position, but also by differences of colour, outline, and texture, and by other peculiarities. A number of them which are fused together to form the cupule of the Oak (*fig.* 197) are hard and woody; in the Hop (*fig.* 216) they are membranous; in certain plants of the *Araceæ* and *Euphorbiaceæ*, coloured; in the flower-heads of the *Compositæ*, scaly; and other modifications also occur.

Sometimes, when a number of bracts are situated in a whorl immediately below the calyx, it is difficult to determine whether they should be considered as a part of the calyx or as true bracts; in most flowers of the order *Malvaceæ*, for instance, we have a circle of leafy organs placed just below the calyx, to which the term *epicalyx* has been given (*fig.* 192).

Almost all inflorescences are furnished with bracts of some kind or other; it frequently happens, however, that some of the bracts do not develop axillary flower-buds, just in the same manner as it occasionally happens that leaves do not produce leaf-buds in their axils. In some cases the non-development of flower-buds in the axil of bracts appears to arise simply from accidental causes; but in others it occurs very regularly; in the Purple Clary (*Salvia Horminum*) and the common Pineapple (*fig.* 167), for example, there are numerous bracts without flower-buds placed at the apex of the inflorescence. Such bracts are called *empty*. When bracts are absent altogether, as is usually the case in the plants of the natural order *Cruciferæ*, and those of the *Boraginaceæ*, such plants are termed *ebracteate*; when bracts are present, the inflorescence is said to be *bracteate*.

Arrangement and Duration of Bracts.—Bracts follow the same laws of arrangement as true leaves, being alternate, opposite, or whorled, in different plants. The bracts of the Pineapple-fruit (*fig.* 167) show in a marked manner a spiral arrangement.

Bracts vary in their duration: when they fall immediately after the flower-bud expands, they are said to be *deciduous*; when they remain long united to the floral axis, they are *persistent*. In some plants they persist and constitute a part even of the fruit: in the Hazel-nut and Filbert they form the *cupule* (*fig.* 198), in the Acorn they constitute the *cup* (*fig.* 197); and in the Hop (*fig.* 216), in the Fir-cones (*figs.* 168 and 243), and Pineapple (*fig.* 167), they persist as membranous, woody, fleshy, or scaly appendages.

Varieties of Bracts.—Bracts have received special names according to their arrangement and other characters. The bracts of that kind of inflorescence called an *amentum* or *catkin*, as seen in the Willow (*fig.* 214), Oak, Hazel (*fig.* 194), Birch, and other plants, are usually of a scaly nature, and are termed *squamæ* or *scales*; or the bracts are described as *squamous* or *scaly*. The bracts of the pistillate flowers of the Hop (*fig.* 215) are of a similar character.

When a circle or whorl of bracts is placed around one flower, as in the Marsh-mallow (*fig.* 192) and Strawberry (*fig.* 193), or around a number of flowers, as in the Carrot (*fig.* 195) and most other Umbelliferous plants, they form what is termed an *involucre*. In some Umbelliferous plants, as, for instance, the Carrot (*fig.* 195), there are two involucres, one at the base of the primary divisions of the floral axis or general umbel, *a*; and another at the base of each of the partial umbels or umbellules, *b*, *b*; the former is then called the *general involucre*; and each of the latter an *involucel* or *partial involucre*. In plants of the natural order *Compositæ*, such as the Marigold (*fig.* 196), Artichoke, Chamomile, and Daisy, and in some allied orders, a somewhat similar arrangement of bracts takes place, and the name of *involucre* is also applied in these cases. In the involucres of the Compositæ there are frequently two or three rows of bracts thus overlapping one another; the constituent bracts of these latter involucres have been termed *phyllaries*. Sometimes the bracts of an involucre grow together at their bases, and form ultimately a sort of cup-shaped body surrounding the fruit, as the cup of the Acorn (*fig.* 197) and the husk of the Filbert or Hazel-nut (*fig.* 198); they then form what is called a *cupule*.

FIG. 194.

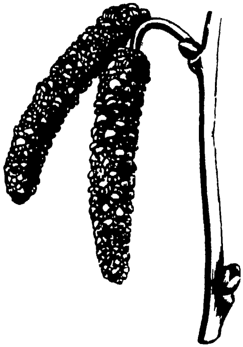


FIG. 195.

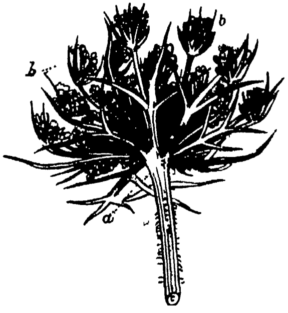


Fig. 194. Staminate or male catkin of the Hazel (*Corylus Avellana*), showing a number of scaly bracts between the flowers.——*Fig.* 195. Compound umbel of the Carrot (*Daucus Carota*). *a*. General involucre. *b*, *b*. Partial involucres or involucels.

When a bract is of large size and surrounds, as a kind of sheath, a single flower or a number of flowers, so as to completely enclose them while they are young, as in the Snowflake (*fig.* 199), the common Arum or Cuckoo-pint (*fig.* 200), and Palms (*fig.* 217), it is called a *spathe*. The spathe is generally found surrounding the kind of inflorescence called a *spadix*, as in the Arum (*fig.* 200) and Palm (*fig.* 218); it is also very common in other Monocotyledons. The spathe may be either green like an ordinary leaf, as in the Cuckoo-pint; or coloured, as in *Richardia æthiopica*. In some Palms these spathes are of great length, occasionally even as much as twenty feet; and as many as 200,000 flowers have been counted in them. Sometimes the spadix of a Palm branches (*fig.* 218), and then we frequently find smaller spathes surrounding its divisions, which have been named *spathellæ*. The term spathe is sometimes

FIG. 196.

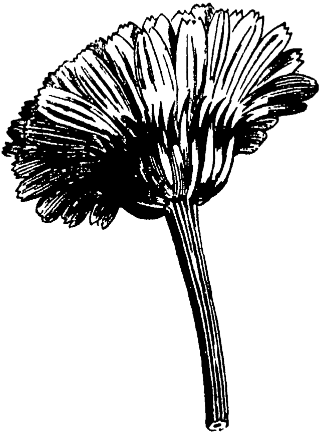


Fig. 196. Capitulum of Marigold (*Calendula*), showing the flowers enclosed in an involucre.

FIG. 197.

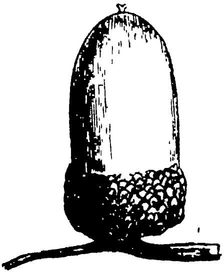


FIG. 198.

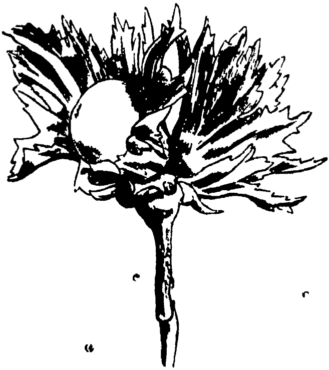


Fig. 197. Fruit of the Oak (*Quercus Robur*), surrounded by a cupule.
Fig. 198. Fruit of the Hazel (*Corylus Avellana*), with a cupule at its base.

restricted to the large enveloping bract of the spadix; the bracts of a similar character, which enclose only a single flower or at most very few, as frequently occurs among Monocotyledons, are then called *spathaceous bracts*.

Besides the bracts which surround the head of flowers of the *Compositæ* and form an involucre, it frequently happens that the individual flowers or florets (*fig.* 201, *a*) are also provided with little bracts, *b*, which are then generally membranous in texture, and colourless, as in the Chamomile. These have received the name of *paleæ*, or—to distinguish them from certain floral leaves found in Grasses which are known by the same name—they may be termed *paleæ of the receptacle*.

FIG. 199.

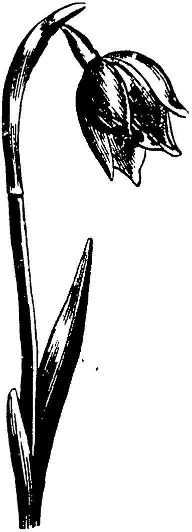


FIG. 200.

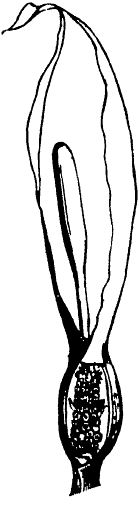


FIG. 201.

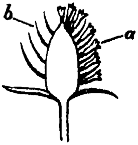


FIG. 202.

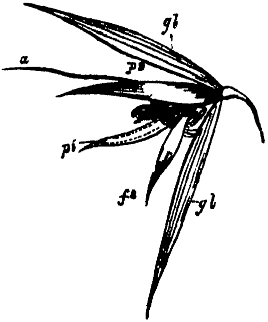


Fig. 199. Flower of the Spring Snowflake (*Leucojum vernum*), arising from the axil of a spathaceous bract or spathe.——*Fig.* 200. Spadix of Cuckoo-pint (*Arum maculatum*) enclosed in a spathe, a portion of which has been removed to show the flowers within.——*Fig.* 201. Receptacle of the Chamomile (*Anthemis nobilis*), bearing tubular flowers (*florets*), *a*, and bracts, *b*; the latter are sometimes termed *paleæ*.——*Fig.* 202. Locusta or spikelet of the Oat (*Avena sativa*). *gl*, *gl*. Glumes. *ps*, *pi*. *Paleæ* or *pales*. *a*. Awn arising from the dorsum of the outer pale, *ps*. *fs*. An abortive flower.

The only other bracts which have received special names are those found in plants of the *Gramineæ* and *Cyperaceæ*. The partial inflorescence of a Grass, which is termed a *locusta* or *spikelet*, has at its base one or two bracts, which are called *glumes* (*fig.* 202, *gl*, *gl*): while in the Cyperaceæ each flower arises from the axil of one or two similar bracts.

2. THE AXIS.

The various kinds of branching that have already been examined have been seen to be three—the *dichotomous*, the *monopodial* or *racemose*, and the *cymose*, usually sympodial. In the inflorescence we find the first of these doubtfully or not at all represented; we have therefore to deal only with the last two. These are sometimes called *Indefinite* or *Indeterminate* and *Definite* or *Determinate* respectively. In the former, the primary floral axis is never terminated by a flower; hence it has the power of either growing in an upward direction, in the same manner as a stem or branch has the power of elongating, and thus adding to its length, or of dilating more or less horizontally. There is consequently no necessary limit to the growth of such an axis, and hence the name of Indeterminate or Indefinite which is applied to it. Such an axis develops flower-buds in acropetal succession as it continues to elongate; from them flowers are produced, and these, like the buds of a stem or branch, are commonly situated in the axils of leaves which are here called bracts, as we have seen. All the flowers, therefore, of an Indefinite Inflorescence must be necessarily *lateral*. This inflorescence is also termed *monopodial*. The general characters of Indefinite, Indeterminate, or Monopodial Inflorescences depend therefore upon the indefinite growth of the primary axis; while the ultimate axes which are developed from it are terminated by flower-buds. In Definite or Determinate Inflorescences, on the contrary, the primary axis is terminated at an early period by the production of a flower-bud; such an axis has therefore a limit at once put to its growth in an upward direction, and hence the names of *Definite*, *Determinate*, or *Terminal*, applied to it.

Each of these primary divisions presents us with several modifications, and a third class is not uncommonly met with, which, as it includes both modes of branching, is commonly spoken of as *mixed* inflorescence.

Before discussing the different forms of these, there are certain peculiarities and varieties of the axis itself which we must consider.

The term *peduncle* is applied to the stalk of a solitary flower, whether axillary (*fig.* 191, *b*, *b*) or terminal (*fig.* 199), and to a floral axis which bears a number of sessile flowers (*figs.* 211 and 212); if the floral axis branches and each branch bears a flower (*figs.* 209 and 210), the main axis is still called a *peduncle*, and the stalk of each flower a *pedicel*; if the axis is still further subdivided, the general name of peduncle is applied to the whole, with the exception of the stalks immediately supporting the flowers, which are in all such cases called pedicels. When the floral axis is thus branched, it is better to speak of the main axis as the *primary* axis (*fig.* 210, *a'*), its divisions as the *secondary* axes, *a''*, and their divisions as the *tertiary* axes, *a'''*, &c.

FIG. 203.

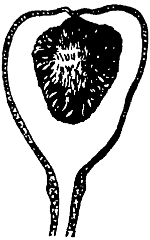


FIG. 204.

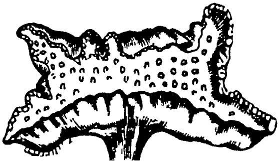


FIG. 205.

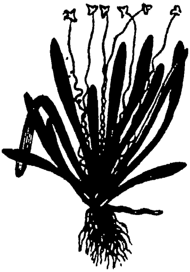


Fig. 203. Hypanthodium of the Fig (*Ficus Carica*), showing pear-shaped fleshy receptacle bearing flowers on its inner surface.——*Fig.* 204. Cœnanthium of a species of *Dorstenia*.——*Fig.* 205. Female plant of *Vallisneria spiralis*, with its flowers arranged on spiral peduncles.

Kinds of Peduncle.—Under certain circumstances peduncles and pedicels have received special names. When a peduncle is elongated, and gives off from its sides sessile flowers (*figs.* 211 and 212), or branches bearing flowers (*figs.* 209 and 210), it is called the *rachis*; but if, instead of being elongated, it becomes more or less dilated, and bears numerous flowers, it is termed the *receptacle*. The receptacle varies very much in form; it is flattened in the Cotton Thistle (*fig.* 223), conical in the Chamomile (*fig.* 201), concave and fleshy in the Dorstenia (*fig.* 204), pear-shaped and hollowed out in the Fig (*fig.* 203). It may assume a variety of other intermediate forms.

It should be observed that the term receptacle is sometimes applied to the extremity of the peduncle or pedicel upon which the parts of the flower are placed. This is, however, preferably called the *thalamus*.

FIG. 206.

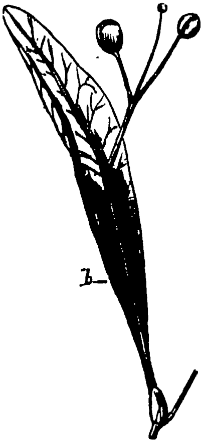


FIG. 207.

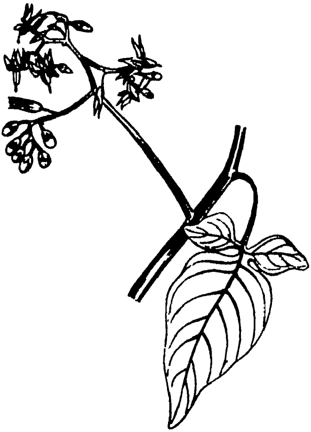


Fig. 206. Peduncle of the Lime-tree (*Tilia europæa*) attached to the bract, *b*. *Fig.* 207. Branch of Woody Nightshade (*Solanum Dulcamara*), with extra-axillary peduncle, and auriculate leaf.

When plants which have no aerial stem bear flowers, the peduncle necessarily arises at the level of, or under, the ground, in which case it is called a *scape* or *radical peduncle* (*fig.* 200), as in the Spring Snowflake, Tulip, Hyacinth, Primrose, and Cowslip. The scape may bear either one flower as in the Tulip, or several flowers as in the Hyacinth.

Forms of Peduncle.—In form the peduncle is generally more or less cylindrical, but besides the departure from this ordinary appearance exhibited by the receptacle just described, and its modifications, it frequently assumes other shapes. It may become more or less compressed, or grooved in various ways, or excessively enlarged during the ripening of the fruit, as in the Cashew-nut;

or it may assume a spiral character, as in *Vallisneria* (*fig.* 205) other modifications also may occur.

Sometimes the peduncle, or several peduncles united, may assume an irregular flattened appearance, somewhat resembling the fasciated branch already described, and may bear numerous flowers in a sort of crest, as in the Cockscomb, and in the Cauliflower, where the united fleshy branches of the peduncle form a rounded mass bearing on its upper part abortive flowers.

Insertion. -In speaking of the branches of a stem, we found that in some cases, instead of arising in the axils of leaves, they become *extra-axillary* in consequence of adhesions of various kinds taking place between them and the stem and other parts. In like manner the peduncle may become *extra-axillary* by contracting adhesions. In the Lime-tree (*fig.* 206) the peduncle adheres to the midrib of the bract, *b*, for some distance, and then becomes free; while in many *Solanaceæ*, as in the Woody Nightshade (*fig.* 207), the peduncle becomes extra-axillary by forming adhesions to the stem or branch in various ways.

We may now proceed to describe the chief forms of inflorescence belonging to the three kinds already mentioned.

Indefinite or Racemose Inflorescence.

This form has been named *botryose* by Eichler, a term which, however, does not seem preferable to the older name *racemose.* As we have said, in this variety of floral arrangement the main axis is never terminated by a flower, but continues for a considerable time to give off flowers just behind its apex. In most cases the axis is elongated to a greater or less degree, and, as from the mode of development the oldest flowers are farthest from its apex, their order of expansion is *acropetal* or *ascending.* In other cases the axis becomes conical, flattened, or even concave at its summit. The growing apex is then at the summit of the cone or lies in the centre of the flattened portion. The youngest flowers consequently appear in that position and the oldest ones are at its periphery. The order of expansion is in these cases said to be *centripetal.*

A number of flowers being thus developed upon an elongated, shortened, or dilated peduncle, several varieties of this kind of inflorescence exist, depending upon the extent to which the floral axis branches, the comparative lengths of the flower-stalks, or their complete suppression, and other subordinate circumstances. The chief forms may be described under three heads: first, those which have an elongated primary axis; second, those in which the primary axis is shortened; third, those in which it becomes dilated and fleshy. The first two may be further subdivided into simple and compound types, the former including those in which the main axis produces flowers only, the latter those in which it develops secondary peduncles on which several flowers arise.

A. *Forms possessing an Elongated Primary Axis.*

1. SIMPLE FORMS.

The simple forms of this class include the Raceme and the Spike, with their varieties.

a. *The Raceme.*—This is the simplest inflorescence of the indefinite type, and from it the name *racemose* is derived. The elongated peduncle bears a number of flowers in acropetal succession, each being furnished with a pedicel. When fully formed the pedicels are nearly of equal length. Examples of it occur in the Currant, Mignonette, Hyacinth, Laburnum, Barberry, Fumitory, &c. Such a form is seen in fig. 208, the raceme of a species of *Prunus*. It will be noticed that the flowers at the lower part of the peduncle are fully expanded, while those at the apex are still in the condition of buds. The acropetal order of expansion is therefore easily observable.

FIG. 208.

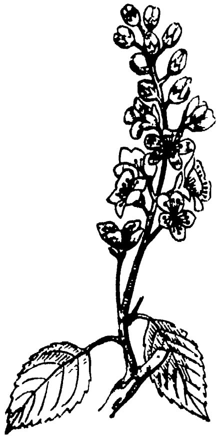


Fig. 208. Raceme of a species of Cherry (*Prunus Padus*).

b. *The Corymb.*—This is a variety of the raceme, in which the pedicels, instead of being of nearly equal length on the peduncle, are of different lengths (*fig.* 209), those (a'', a'') at the base of the primary axis a' being longer than those towards and at the apex, so that the whole form a level, or nearly level, top. Examples may be seen in some species of *Prunus* (*fig.* 209). It frequently happens that after flowering the primary axis elongates, and the corymb becomes a raceme; this may be seen in many Cruciferous plants, such as the Wallflower or Stock.

c. *The Anthela.*—In several species of *Juncus* and *Luzula* the pedicels of the lower flowers are so long that they are elevated above the upper ones. The form of the inflorescence so becomes concave on the upper surface. This variety is known as the *anthela*.

d. *The Spike.*—This differs from the raceme only in the flowers being sessile on the main peduncle; or if there are any pedicels, they are so short as to be indistinguishable without removing the flowers from the axis. Examples of it may be seen in the Rib-grass (*fig.* 211) or the Vervain (*fig.* 212).

There are four kinds of indefinite inflorescence which are modifications of the spike. These are the *Amentum* or *Catkin*, the *Spadix*, the *Locusta* or *Spikelet*, and the *Strobile*.

FIG. 209.

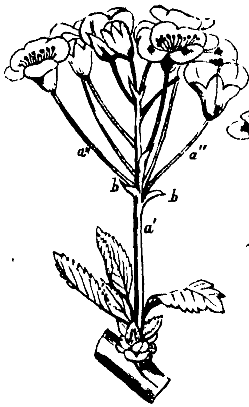


FIG. 210.

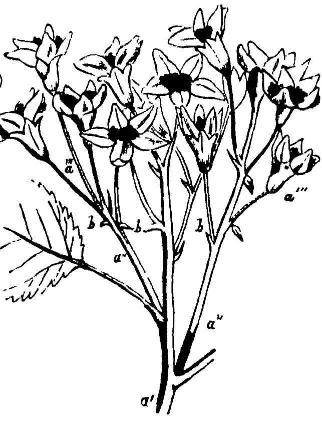


Fig. 209. Simple corymb of a species of *Prunus* (*Cerasus*). *a'*. Primary axis, bearing bracts, *b*, *b*, from the axis of which pedicels, *a''*, *a''*, arise. *Fig.* 210. Compound or branching corymb of the Wild Service tree (*Pyrus torminalis*). *a'*. Primary axis. *a''*, *a''*. Secondary axes. *a'''*, *a'''*. Tertiary axes. *b*, *b*, *b*. Bracts.

e. *The Amentum or Catkin.*— This is a kind of spike which usually bears monosporangiate flowers—that is, only staminate (*fig.* 214), or only pistillate (*fig.* 215) ones. The axis or rachis is usually of a very weak character, so that the catkin is pendulous. The flowers of an amentum are also usually separated from one another by scaly bracts. The staminate catkins commonly fall off in one piece, soon after the process of flowering. The bracts have in some cases *one* flower and in others *several* in their axils. All plants with this kind of inflorescence are called *amentaceous* or *amentiferous*. Our trees afford numerous examples, as the Oak, Willow, Birch, and Poplar.

f. *The Spadix* is a spike with a succulent axis in which the individual flowers have no special bracts, but the whole inflorescence is enclosed in that variety of bract which is called a spathe. This is well seen in the Cuckoo-pint (*fig.* 200), where the spadix included in the spathe bears staminate and pistillate flowers, the latter being nearest its base. The term spadix is also usually applied to a succulent spike, whether enveloped in a spathe or not, as in the Sweet Flag (*Acorus Calamus*).

FIG. 211. FIG. 212. FIG. 213.

Fig. 211. Spike of a species of Rib-grass (*Plantago*).——*Fig.* 212. Spike of Vervain (*Verbena*).——*Fig.* 213. Inflorescence of Wheat (*Triticum vulgare*), consisting of numerous sessile spikelets arranged on an elongated peduncle (*rachis*).

g. *The Locusta or Spikelet.*—This name is given to the ultimate branches of the inflorescence of Grasses (*fig.* 202) and Sedges. In the Grasses it is a spike with a few flowers, and these destitute of a true calyx and corolla, their place being occupied by *paleæ* or *pales* (*fig.* 202, *ps*, *pi*), and the whole inflorescence surrounded at the base by one or two empty bracts

FIG. 214.

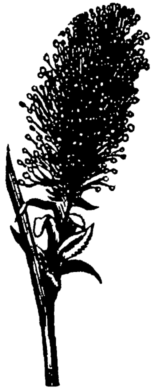


FIG. 215.

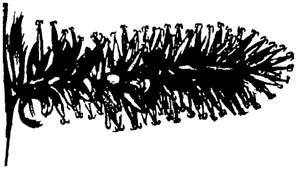


Fig. 214. Staminate amentum or catkin of a species of Willow (*Salix*).——*Fig.* 215. Pistillate or carpellary amentum of a species of Willow, with bracts between the flowers.

(*glumes*), *gl*, *gl*. These spikelets may be either sessile on the elongated peduncle or rachis, as in the Wheat (*fig.* 213), or they may be placed on a more or less branched axis, as in the Oat (*fig.* 220).

h. *The Strobile.*—This is a kind of spike formed of persistent membranous bracts or scales, each of which bears at its base a pistillate flower. It is seen in the Hop (*fig.* 216).

FIG. 216.

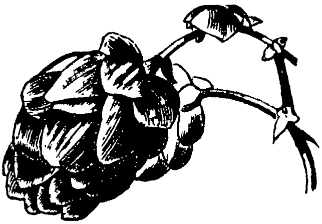


Fig. 216. Strobile of the Hop (*Humulus Lupulus*).

2. COMPOUND FORMS.

The compound forms of the racemose type of inflorescence include all the modifications of those already described in which the main peduncle bears secondary peduncles instead of single flowers in the axils of the bracts. The following are the chief varieties.

i. *The Panicle.*—This is a compound raceme, or one in which the secondary peduncles bear racemes (*fig.* 217). The secondary axes may themselves branch in the same way as the primary one and form tertiary axes, &c., the ultimate subdivisions of which bear the flowers. For an example we may take the *Yucca gloriosa*.

Sometimes the ultimate racemes are represented by spikelets, as in the Oat (*fig.* 220).

k. *The Compound Corymb.* -This may be seen in some species of *Pyrus* (*fig.* 210). It is sometimes called a *panicled* corymb. It differs from the panicle as the corymb differs from the raceme.

l. *The Compound Spike.*– An instance of this is seen in the Wheat and certain other grasses.

FIG. 217.

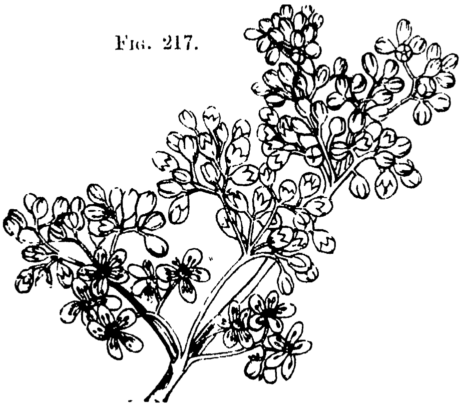


Fig. 217. Panicle.

m. *The Compound Spadix.*—This form is seldom met with, as the spadix does not often branch. Instances may be seen in the Palms (*fig.* 218).

B. *Forms possessing a Shortened Primary Axis.*

Of these we distinguish the simple and the compound Umbel.

n. *The Umbel.*—When the primary axis is shortened, and gives off from its apex a number of secondary axes or pedicels of nearly equal length, each bearing a flower, an *umbel* is formed, as in the Onion and Cowslip (*fig.* 222). When the secondary axes themselves divide, and form tertiary axes, which are also arranged in an umbellate manner, a *compound umbel* is produced. This is seen in the Carrot (*fig.* 195), the Fennel (*fig.* 221), and other allied plants, which are hence called *umbelliferous*, and give the name to the Natural Order *Umbelliferæ*. In the compound umbel (*fig.* 221), the primary umbel *a* is called the *general umbel*, and the other umbels, *b*, *b*, *b*, formed by the division of this, *partial umbels* or *umbellules*. When the base of the general umbel is surrounded by a whorl of bracts (*fig.* 195, *a*), they constitute a *general involucre*: and if other bracts, *b*, *b*, are arranged in a similar manner around the partial umbels, each of these whorls of bracts forms an *involucel* or *partial involucre*. These varieties of arrangement have already been alluded to when speaking of bracts.

FIG. 218.

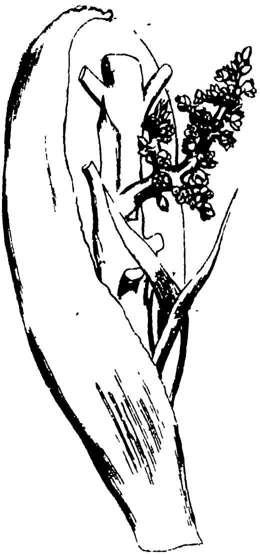


FIG. 219.

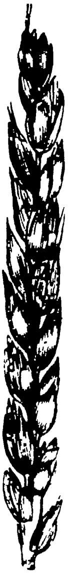


FIG. 220.

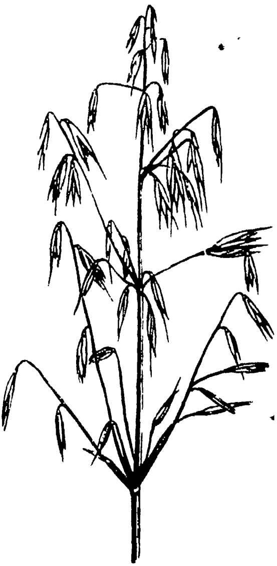


Fig. 218. Branched spadix of a Palm (*Chamærops*), enveloped in a spathe. *Fig.* 219. Inflorescence of Wheat (*Triticum vulgare*), consisting of numerous sessile spikelets arranged on an elongated peduncle (*rachis*).—*Fig.* 220. Branched or panicled arrangement of the spikelets of the Oat (*Avena sativa*).

When an umbel springs laterally from a stem in such a way that there is no primary peduncle at all, it is sometimes called a *fascicle.* It must not, however, be confused with the fascicle which is a variety of the polychasium (page 120).

FIG. 221.

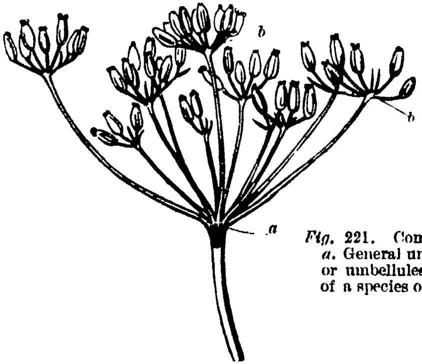


FIG. 222.

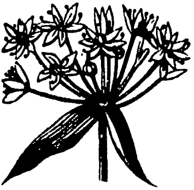


Fig. 221. Compound umbel of Fennel. *a.* General umbel. *b, b, b.* Partial umbels or umbellules.——*Fig.* 222. Simple umbel of a species of Allium.

C. *Forms with a Dilated Fleshy Axis.*

These can be seen to be constructed in the same way as the raceme. In the latter the main axis is a very much elongated cone, and each flower or branch is subtended by its bract. In the simplest forms of the flattened type the cone becomes very much shortened and dilated at its base, so that the order of expansion of the flowers is centripetal rather than acropetal. In the more complicated ones the conical form, by the still further dilatation of the basal region, becomes converted into a flattened or even cup-shaped receptacle. The bracts of the lower portion of the axis may be aggregated together at the base of the receptacle and form an

FIG. 223.

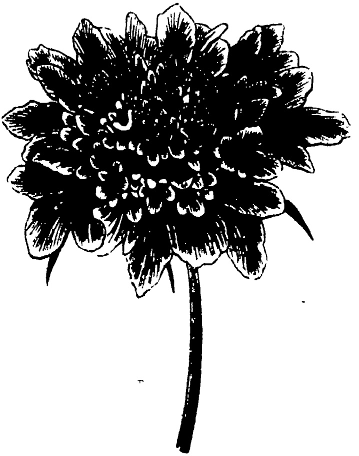


Fig. 223. Capitulum of Scabious (*Scabiosa*). The outermost florets may be observed to be more expanded than the inner.

involucre. In many cases, however, they are suppressed entirely. Of this form of inflorescence we have three varieties, the *capitulum*, the *cœnanthium*, and the *hypanthodium*.

o. *The Capitulum, Anthodium, or Head.*—This inflorescence is usually formed by a number of sessile flowers or florets crowded together on a receptacle, and the whole surrounded by an involucre (*fig.* 223); but in some cases the florets are few in number, while from other capitula the involucra are absent. The receptacle, as we have seen, may be either flattened, as in the Cotton Thistle (*fig.* 224); or slightly concave, or slightly convex as in the Dandelion; or conical, as in the Chamomile.

FIG. 224.

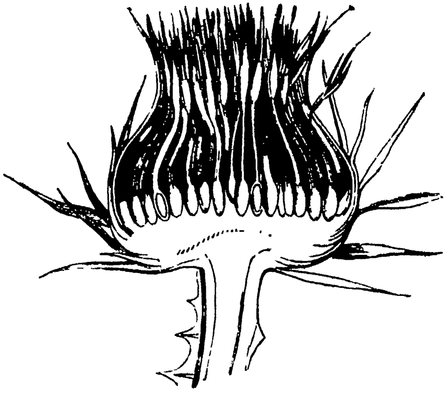


Fig. 224 Capitulum of Cotton Thistle (*Onopordum Acanthium*).

The capitulum is the universal form of inflorescence in plants of the Natural Orders *Compositæ* and *Dipsaceæ*; it also occurs occasionally in some others.

p. *The Cœnanthium.*—When, as in *Dorstenia* (*fig.* 226), the receptacle is nearly flat, but its margins are slightly curved upwards, and the flowers very minute and embedded in it, we have a form which has been termed a *cœnanthium*.

q. *The Hypanthodium.*—This form is shown in the Fig (*fig.* 225). The receptacle, which is conical in the capitulum, and is slightly concave, with turned-up rim, in the cœnanthium, in the hypanthodium becomes a hollow cup, almost or completely closed at the apex and having the flowers arranged all over the inside surface. The involucre, which is so prominent a feature of the capitulum, is absent from the hypanthodium.

Many of these types are found to merge into each other, and the identification of some forms becomes difficult. The only difference between the spike and the raceme being one of length of pedicel, and this being a very variable part, it is evident that the line of classification becomes somewhat arbitrary. The inflorescence may change its character as it grows older, as has already been pointed out in the case of the corymb. Difficulties of identification also sometimes arise in consequence of the modification and suppression of bracts, and various distortions that may occur during growth.

Fig. 225.

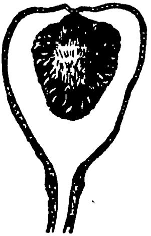


Fig. 226.

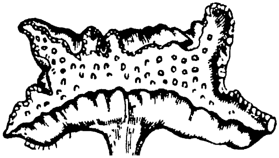


Fig. 225. Hypanthodium of the Fig (*Ficus Carica*), showing pear-shaped fleshy receptacle bearing flowers on its inner surface.— — *Fig.* 226. Cœnanthium of a species of *Dorstenia*.

Definite or Cymose Inflorescence.

In all kinds of definite inflorescence the primary axis, as we have seen, is arrested in its growth at an early age by the development of a terminal flower-bud. If the axis bears no other flower, this is called a *solitary terminal* flower, and is the simplest form of this variety of inflorescence. Examples of it may be seen in the Stemless Gentian (*fig.* 228), and in the Wood Anemone. When other flowers are produced on such an axis, they must necessarily arise from axillary flower-buds placed below the terminal one; these form secondary axes (*fig.* 227, a'), each of which in like manner is terminated by a flower-bud, f''; if further axes, a''', are developed from the secondary ones, these also must be axillary, and end in a similar manner in flowers, f'''; these axes may also form other axes of a like character, and so on. Hence this mode of inflorescence is *definite*, *determinate*, or *terminal*, in contradistinction to the former or indefinite mode of inflorescence already described, where the primary axis continues to grow in length, and never ends in a flower. Definite inflorescences are most common and regular in plants with opposite or whorled leaves, but they also occur in those which have alternate leaves, as may be seen in the species of *Ranunculus* (*fig.* 227). In definite inflorescences the flower-buds necessarily follow a different order of expansion from those of indefinite inflorescences. In them the terminal flower is the oldest and consequently the first developed (*fig.* 227, f'), and other flower-buds are produced in succession, either from the apex towards the base of the plant, if the axis is elongated, f'' f'''; or from the centre towards the circumference, if it is shortened or dilated. The uppermost flower-bud of the elongated primary axis (*fig.* 227, f'), and the central one of the shortened or dilated axis, open first; and the expansion of the other flower-buds proceeds in succession downwards, or towards the circumference, according to the character of the primary axis. Such an order of expansion is called *centrifugal*. Hence, while the indefinite kinds of inflorescences are characterised by an *acropetal* or *centripetal* order of expansion, those of definite inflorescences are *centrifugal*. The name *cyme* is given to many-flowered inflorescences of this type.

FIG. 227.

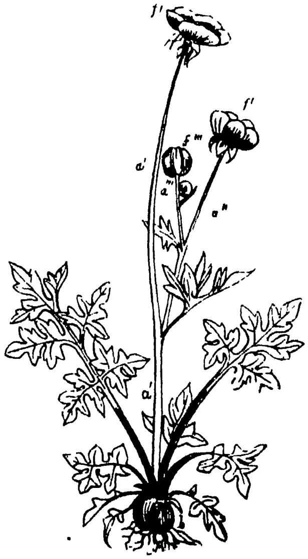


Fig. 227. A plant of *Ranunculus bulbosus*. a', a'. Primary axis terminated by a fully expanded flower, f'. a''. Secondary axis, which is also terminated by a flower, f'', not so fully developed as f'. a'''. Tertiary axis, terminated by a flower-bud, f'', which is less developed than f' and f''.

A. *Forms of Cymose Inflorescence with no Pseud-axis.*

a. *The Solitary Terminal or Axillary Flower.*—The simplest kind of inflorescence of the cymose type is that presented by such plants as the Pimpernel (*fig.* 191), in which solitary flowers, *b*, *b*, are developed in the axis of what are commonly regarded as the ordinary foliage leaves of the plant, *a*, *a*. The primary axis of the plant bears thus several secondary axes, each ending in a flower, which is therefore axillary when considered in relation to the primary axis, but terminal as regards the secondary one. The main axis itself terminates in a flower in the cases of the Gentian (*fig.* 228) and the Anemone already alluded to. When such flowers are arranged in whorls round the stem, as in *Hippuris*, each flower being in the axil of a leafy bract, they are said to be *whorled* (*fig.* 229).

FIG. 228.

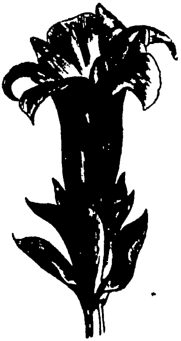


FIG. 229.

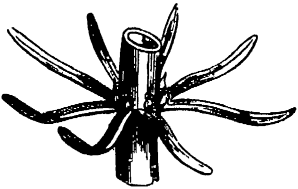


Fig. 228. Solitary terminal flower of *Gentiana acaulis.*——*Fig.* 229. Whorled leafy bracts and solitary axillary flowers of Mare's Tail (*Hippuris vulgaris*).

b. *The Dichasium.*—In this variety the main peduncle is terminated by a flower, and some little distance behind the apex two opposite bracts occur, from the axil of each of which another peduncle arises, terminated in like manner by a flower. Each secondary peduncle in like manner gives rise to two more flowers. This order of development may be continued for some time, an inflorescence of considerable size resulting, as in *Erythræa Centaurium* (*fig.* 231). Very frequently the axes of high order give rise to only one flower instead of two, the other with its bract not being developed. The dichasium, from the regularity of its forking, is sometimes called a *false dichotomy.* It can be distinguished from a true dichotomy by the presence of a flower in the angle of the fork.

A diagram of the dichasium is given in figure 234 A.

c. *The Polychasium.*—This differs from the dichasium only in having more than two secondary axes springing from each peduncle below its terminal flower. Frequently the primary terminal flower is suppressed, so that the secondary axes appear to originate at the apex of the main peduncle without reference to a flower. The true nature of the inflorescence can, however, be seen from the fact that the order of expansion of the flowers is centrifugal. Examples can be seen in the Laurustinus (*fig.* 232), and others.

FIG. 230.

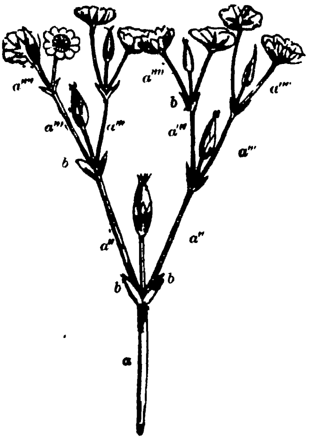


FIG. 231.

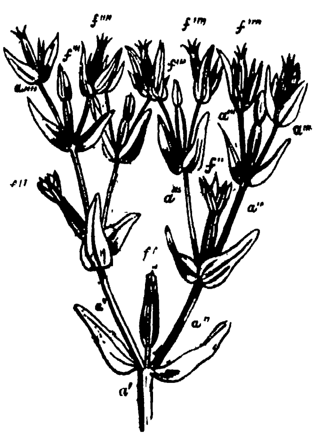


Fig. 230. Dichasial cyme or dichasium of a species of *Cerastium*. a. Primary axis terminated by a flower. a'', a''. Secondary axes, two in number, arising from the axils of opposite bracts, b, b, and terminated also by flowers. a''', a''', a''', a'''. Tertiary axes, four in number, arising from bracts, b, and bearing other bracts, b, from which the quaternary axes, eight in number, arise, a'''', a'''', a''''. The flowers are more developed on the primary axis than on the other axes; thus the one terminating that axis is in the state of fruit: the flowers of the axes of a'' and a''' are also in fruit, but less developed than that of a', while in the axes a'''' the flowers only are expanded.——*Fig.* 231. Dichasial cyme or dichasium of the Centaury (*Erythræa Centaurium*). a', a'', a''', a''''. Floral axes. f', f'', f''', f''''. Flowers terminating those axes respectively. The flowers will be observed to be most developed in proportion to their age; thus f' is in the state of fruit; f'', f'', expanded; f''', f''', f''', and the others still in bud.

A good deal of complication often arises from suppression of the bracts, or from distortion due to condensation of the internodes or to irregularities in growth. An example of this kind may be found in the inflorescence of the Sweet William, a member of the *Caryophyllaceæ*. This has been called a *fascicle.* In it the successive axes are developed so as to bear their flowers at the same level, forming a flat-topped cyme, which superficially resembles a corymb.

FIG. 232.

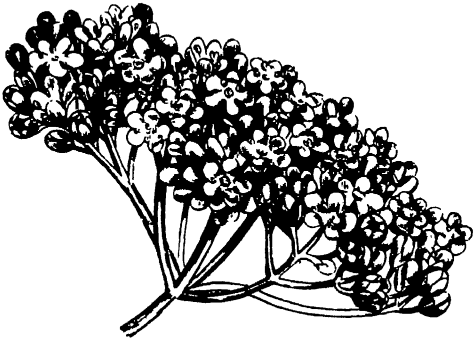


Fig. 232. Polychasial cyme of Laurustinus (*Viburnum Tinus*).

d. *The Cymose Umbel.*—This differs from the polychasium in having the main axis as long as, or longer than, the secondary ones, a number of which arise some little distance below its apex. The secondary axes do not give rise to tertiary ones, so that the form of the true or racemose umbel is simulated. The order of expansion of the flowers reveals its true nature. Examples are seen in the Pelargoniums.

FIG. 233.

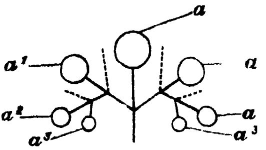


Fig. 233. Diagram of Verticillaster, a, a^1, a^2, a^3, successive axes, each terminated by a flower. The dotted lines indicate the positions of the suppressed branch of each axis.

e. *The Verticillaster.*—This is a very much condensed cyme, the flowers of which have very short pedicels, and therefore appear almost sessile. The first axis gives rise to two branches, but the latter and their succeeding branches generally bear only one each (*fig.* 233). The whole verticillaster appears much like a cluster of sessile flowers. Instances of it are afforded by most plants of the natural order *Labiatæ*, which bear two such cymes in the axils of opposite leaves, so that the flowers appear to surround the stem. A pair of such axillary cymes is sometimes called a *glomerule* (*fig.* 190).

B. *Forms of Cymose Inflorescence with a Pseud-axis.*

These can be understood by a comparison of them with the dichasium (*fig.* 234). Instead of the main peduncle bearing two bracts each with a secondary axis in its axil, only one is produced, the other being suppressed; this secondary axis behaves like the primary one, bearing only one tertiary axis. This mode of development may be continued for some time, and thus, by the coalescence of the parts of the successive branches below the bract which each bears, a central axis, or rather *pseud-axis*, is produced, which is at first zigzag or curved in shape, but which frequently becomes straightened during subsequent growth. This kind of inflorescence is called a *sympodial cyme.*

FIG. 234.

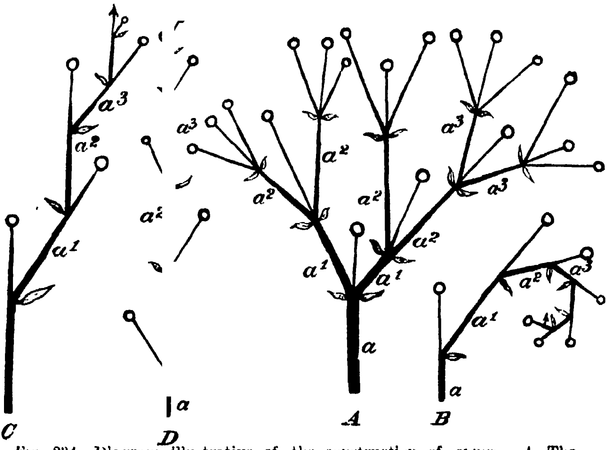


Fig. 234. Diagram illustrative of the construction of cymes. *A*. The dichasium. *B*. The helicoid cyme. *C*. *D*. The scorpioid cyme. *a*, *a*¹, *a*², *a*³, the successive axes. The fusion of portions of the latter to form the sympodium is indicated by the thickened lines. *D* represents the condition of *C* after growth has straightened the sympodium.

The bracts of the suppressed axes are generally not developed, but can occasionally be found. In any case the true nature of the inflorescence may be ascertained by noticing the relation of the bracts to the flowers. In the raceme this relationship is unmistakable; in the sympodial cyme a bract appears opposite to the flower upon the axis; this showing that the flower is really terminal, and the portion of the axis between it and the bract is a part of a sympodium (*fig.* 235).

When development is normal each flower is subtended by a bract; that is, it arises in the axil of the latter.

We can distinguish two forms of the sympodial cyme.

f. *The Helicoid Cyme.*—This form is produced when the suppression of the successive axes takes place on the same side, causing the sympodium to be curled up in the manner of a helix (*fig.* 234, *B*). The successive axes may be developed in a plane at right angles to that of the main peduncle and its first branch, or in one which is parallel to it. Eichler distinguishes the latter under the name of the *drepanium.*

FIG. 235.

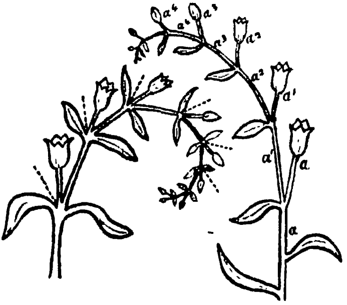


FIG. 236.

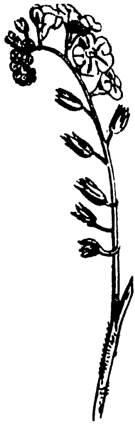


Fig. 235. Instances of helicoid cymes (after Gray). The successive axes, *a*, *a*¹, *a*², &c., are each terminated by a flower, and each arises on the antecedent axis in the axil of a bract. In the figure on the right, both bract and secondary axis are suppressed continuously on the right-hand side. In the figure on the left, both bracts are represented, and the axis which is suppressed is indicated by a dotted line.——*Fig.* 236. Helicoid cyme of the Forget-me-not (*Myosotis palustris*).

Examples of the helicoid cyme may be found in many *Boraginaceæ*, as the Forget-me-not (*fig.* 236) and the Comfrey (*fig.* 237).

g. *The Scorpioid Cyme.*—In this form, instead of the branches being suppressed uniformly upon the same side of the dichasium, the suppression takes place on the two sides alternately (*fig.* 234, *C*, *D*). Subsequent growth generally causes the sympodium, which is at first zigzag in form, to become straight. The parts of each axis above the insertion of the branch remain weak and are displaced laterally, causing the inflorescence to simulate the raceme, from which, however, it can be distinguished by the position of the bracts, as already described.

As in the last case, the branches may arise in the plane of the original dichasium, or in one at right angles to it. Eichler distinguishes the former under the name of the *rhipidium* (*fig.* 238).

The scorpioid cyme may simulate the corymb, as in the figure last referred to, where the lengths of the successive axes are such as to bring the flowers to the same height. It can be distinguished from the true corymb by the position of the bracts, and by the originally zigzag shape of the sympodium. Sometimes the bracts are not developed, when it becomes very difficult to determine the true composition of this inflorescence.

FIG. 237.

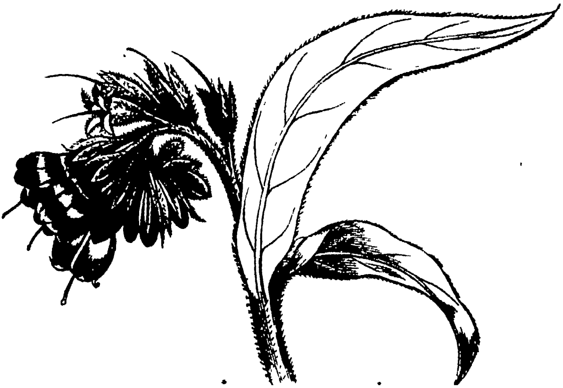


Fig. 237. Helicoid cyme of Comfrey (*Symphytum officinale*).

Instances of the scorpioid cyme are found in the Sundew (*Drosera*), the Rock-rose (*Helianthemum*), &c.

Mixed Inflorescences.

This kind of inflorescence is by no means uncommon. The term is applied to such collections of flowers as show a conjunction of both the types already discussed. Various degrees of complexity can be found, of which the simplest occur when the general inflorescence develops in one way and the partial or individual inflorescences in the other. In some plants of the natural order *Compositæ* (*fig.* 239), the terminal capitulum is the first to expand, and the capitula, as a whole, are therefore developed in a centrifugal manner; while the individual capitula, as we have seen, open their florets from the circumference to the centre, or centripetally; hence, here the general inflorescence

FIG. 238.

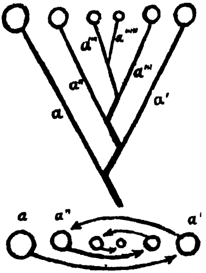


FIG. 239.

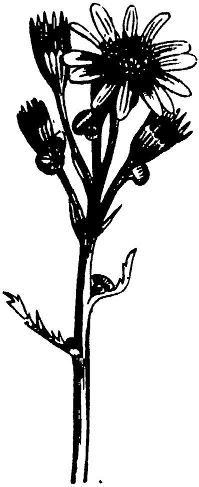


FIG. 240.

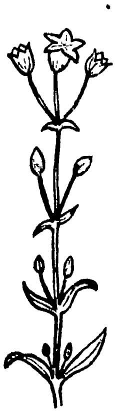


Fig. 238. Diagram of the Rhipidium. The successive axes are marked *a*, *a'*, *a''*, &c. The basal portions of each being thicker than the rest, a sympodium of zigzag form results, as seen in the centre of the figure. The order of expansion is seen in the lower figure as viewed from above.—*Fig.* 239. Mixed inflorescence of a species of *Senecio*.—*Fig.* 240. Figure of the reversed raceme (after Gray).

is *definite*, and each partial inflorescence *indefinite*. In the *Labiatæ* we have the contrary arrangement, for the individual verticillasters open their flowers centrifugally (*fig.* 238), but the general inflorescence is centripetal.

The following forms also illustrate mixed inflorescence.

a. *The Reversed Raceme.*—This, though of the cymose type, is arranged somewhat like the true raceme, inasmuch as the main axis is stronger than its branches, but these are developed basipetally upon it (*fig.* 240). The oldest flower terminates the main peduncle, two younger ones arise from the axils of the uppermost bracts, two still younger ones form those of the next pair, and so on for a variable distance down the axis.

The ultimate cymes of a polychasium often assume this form (*fig.* 232).

FIG. 241.

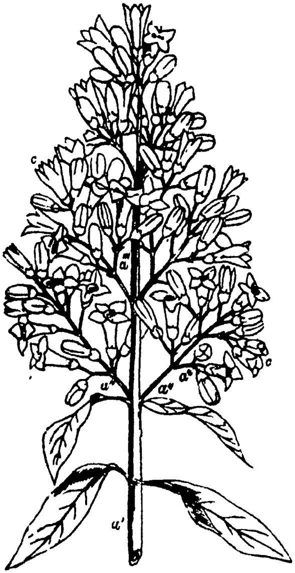


FIG. 242.

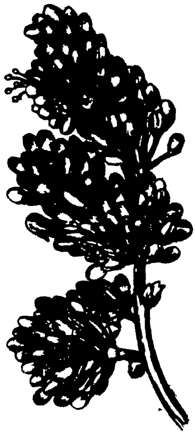


Fig. 241. Mixed panicle of the Privet (*Ligustrum vulgare*). a'. Primary axis. a'', a''. Secondary axes. a''', a'''. Tertiary axes. *c*, *c*. The central flowers of the respective clusters, which are seen to be in a more expanded state than those surrounding or below them.——*Fig.* 242. Thyrsus of Vine.

b. *The Mixed Panicle.*—This is a compound inflorescence in which the main axis is racemose and the secondary ones are irregular. A great many cases occur in which a repeatedly branching inflorescence of the panicle type changes its mode of forming branches in its latter ramifications. In the panicle of the Privet (*fig.* 241) we have the two methods illustrated. The main axis is racemose in its general arrangement, but it bears a terminal flower; the secondary and later axes are reversed racemes.

c. *The Thyrsus.*—This is somewhat more regular than the mixed panicle, which it resembles in having the main axis racemose. The secondary and later ones are cymose, and the successive branches are so disposed that the cluster is narrower at the apex and base than it is in the centre, having thus almost the shape of a double cone. Examples are seen in the inflorescence of the Lilac and the Horse-chestnut. An almost compound thyrsus is seen in the Vine (*fig.* 242).

Light is often thrown upon the construction of the forms of the inflorescence by the study of the phyllotaxis of the plant. The racemose types are found associated with both verticillate and alternate leaves, but the generally marked acropetal development makes their interpretation easy. More difficulty is found in analysing some of the cymose forms. The dichasium most frequently occurs together with verticillate, and particularly with opposite decussate leaves. A polychasium may result from the suppression of alternate internodes, the result being that, instead of two, four axes of the dichasium arise together, the two younger being at right angles to the two older. In the Elder (*Sambucus*) there are apparently five such axes, springing from the same point, thus simulating an umbel. The five axes consist of the primary one and two successive pairs, which are severally somewhat distorted in growth; each axis bears several subordinate ones, which may be similarly arranged, and each ultimately bears several flowers.

In some helicoid cymes, the flowers, which are seated on the convex side of the curved sympodium, arise in two ranks instead of one. This has been explained as a unilateral raceme, but there appears to be little doubt that its true nature is cymose. The appearance of two ranks of flowers is explained by Eichler on the ground of *antidromy.* The phyllotaxis in such cases is spiral, and the genetic spiral, instead of passing regularly from right to left round the axis, becomes reversed in the successive parts of the sympodium, travelling in the first from right to left, in the second from left to right, and then again reversing its direction. Examples are seen in many of the *Boraginaceæ.*

It is held by some botanists that in a few of the plants of the last-named Natural Order, where the inflorescence is apparently a helicoid cyme or a unilateral raceme, the branching of the successive axes is not lateral but dichotomous, the growing point of each axis after the first dividing into two equal parts; one of the resulting branches speedily terminates in a flower, while the other again dichotomises.

3. THE FLOWER.

The term *flower* may be applied to any shoot which is specially modified in connection with spore-production. The term is usually, but erroneously, restricted to the Phanerogams, in which this modification results in a structure generally of peculiar form and often of great beauty and fragrance. Flowers, however, of a lower type of complexity than these can be recognised in the *Pterido-phyta*. The common Horsetail (*Equisetum*) has its sporangia arranged upon a number of peltate sporophylls which are aggregated in the form of a cone at the apex of certain shoots (*fig*. 243). These constitute a flower which resembles the cones or flowers often found in the group of Phanerogams known as Gymnosperms (*fig*. 244). Similar arrangements are found among the *Lycopodinæ*, or Club-mosses. In the so-called flowering plants the flowers are the ultimate branches or shoots of the inflorescence. They consist usually of an axis bearing leaves, of which some are *sporophylls* and bear the sporangia, others are *perianth leaves* and have only a function subordinate to the former. The apex of the axis itself sometimes constitutes the flower, as in the Yew-tree, where particular branches bear at their apex a terminal megasporangium or ovule, which is not protected by any foliar structures. In a few cases some of the sporangia are borne by the axis, and others by the sporophylls, as in the *Polygonaceæ*, the Dock family. The axis here terminates in a megasporangium much as in the Yew, but this is covered in by a foliar outgrowth called the ovary. Lower down on the axis are certain sporophylls, the stamens, which bear the microsporangia, while below these again are certain perianth leaves.

FIG. 243.

FIG. 244.

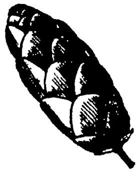


Fig. 243. Cone of Horsetail (*Equisetum*).——*Fig.* 244. Cone of Hemlock Spruce (*Pinus canadensis*).

The phyllotaxis of the flower, like that of the vegetative shoot, may be either alternate or whorled. In the former case the leaves describe a spiral round the axis; in the latter they form generally four definite whorls or series. Instances of the former may be seen in the flowers of *Pinus* and other Conifers, and among the higher plants in the Water-lily.

Spiral phyllotaxis is most usual in the Gymnosperms, and whorled in the Angiosperms.

In one of the most highly organised of the flowers of the latter group we can recognise four whorls of leaves arranged upon an axis or thalamus. Usually the thalamus is terminated by the ultimate whorl of leaves, but in some cases it grows out beyond it, and may then bear a number of ordinary foliage leaves. This is, however, regarded as altogether abnormal, and only occurs in consequence of some disturbance of nutrition. The internodes of the axis between the whorls of leaves are usually but little developed, so that the latter are very closely pressed together.

The lower two whorls of leaves constitute the perianth, and do not bear sporangia. The other two are sporophylls, and bear microsporangia and megasporangia respectively.

The most external of the perianth whorls is known as the *calyx*, and its leaves are called *sepals*. They are usually green and commonly sessile; they resemble foliage leaves in structure and sometimes in appearance; they are protective in function.

The second whorl is the *corolla*, and its leaves are *petals*. They are generally brightly coloured and delicate in texture. In many cases they are stalked, when the stalk is termed the *claw*, and the blade the *limb*.

In some flowers the calyx and corolla are very similar in appearance, being either green or *sepaloid*, or coloured or *petaloid*. In a few cases they stand so closely together that it is difficult to see that there are two whorls present. In such cases it is usual in describing the flower not to speak of calyx and corolla, but to make use of the term *perianth* without distinguishing its constituent whorls.

The third whorl is made up of the first set of sporophylls, and bears the microsporangia. This whorl is generally called the *andrœcium*, and its separate parts are *stamens*. These leaves are much modified in form, consisting of an upper swollen portion, the *anther*, supported upon a somewhat slender stalk or *filament*. The anther is sometimes sessile, the filament not being developed. Each anther usually contains either two or four *pollen-sacs*, or microsporangia, in which are developed the microspores or pollen-grains.

The final whorl, which usually terminates the axis, is known as the *pistil* or *gynæcium*. The sporophylls of which it is composed are called *carpels*, and may be distinct from each other or united in various ways to form a solid body. The Buttercup and the Poppy are instances of these cases respectively.

Each carpel, or the body formed by their union, consists of a hollow inferior part, the *ovary*, and a terminal sticky portion, the *stigma*. The stigma is sometimes sessile on the ovary, but is generally separated from it by a slender stalk-like portion, the *style*. The megasporangia or *ovules* are developed in the interior of the ovary, generally arising from a fleshy development of the edges of the carpel known as the *placenta*. Sometimes the placenta is borne upon the axis, and not upon the carpel.

The true nature of the union of the carpels with each other will be discussed in a succeeding section.

It is customary to regard the carpels as sporophylls, even in those cases in which the megasporangia really spring from the axis, which in these cases protrudes into the cavity of the ovary, as in the *Polygonaceæ*, already mentioned. Other instances of this are found in the *Primulaceæ*, the Primrose family.

Other structures are occasionally to be met with in certain flowers. In some of the genera of the *Boraginaceæ* and the *Caryophyllaceæ* a *scale* or *ligule* is found at the junction of the claw and the limb of the petals (*figs.* 308 and 327). In the Daffodil (*fig.* 328) these scales or ligules are coherent together and form a tubular structure known as the *corona*. Many flowers contain certain bodies which excrete a sugary liquid. These are called *nectaries*. They have no definite position like the parts already described, but may arise from the metamorphosis of various structures. Certain foliaceous scale-like bodies known as *staminodes* may be found in some flowers. They may be of various shapes and sizes. These are always formed by the metamorphosis of a stamen.

Symmetry of the Flower.

The term 'symmetry' has been variously understood by different botanists. It was formerly usual to describe a flower as symmetrical when all the whorls of its members have an equal number of parts, or when the parts of one whorl are a multiple of those of another. Such a flower is preferably to be described as *isomerous*. In some species of *Crassula* (*fig.* 245) we have a flower composed of five sepals, five petals, five stamens, and five carpels; in *Sedum* (*fig.* 246) we have five sepals, five petals, ten stamens in two whorls, and five carpels; in the Flax we have five sepals, five petals, five stamens, and five carpels, each of which is partially divided into two by a spurious dissepiment (*fig.* 421); in *Circæa* (*fig.* 247) we have two members in each whorl; in the Rue (*fig.* 282) we have four or five sepals, four or five petals, eight or ten stamens, and a four- or five-lobed pistil; and in the Iris there are three members in each whorl. When the number of parts in each whorl is not the same, or when the parts of the largest whorl are not a multiple of those of the smallest, the flower is *heteromerous*, as in *Verbena*, where the perianth has five parts in each whorl, and the sporophylls only four.

FIG. 245.

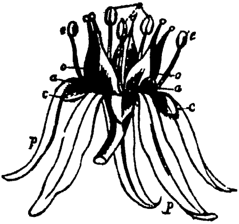


FIG. 246.

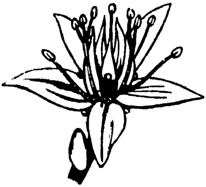


Fig. 245. Flower of *Crassula rubens.* *c, c.* Sepals. *p, p.* Petals. *e, e, e.* Stamens. *o, o.* Carpels, at the base of each of which is seen a scale, *a, a.* *Fig.* 246. Flower of a *Sedum.*

FIG. 247.

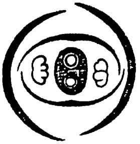


FIG. 248.

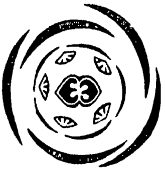


Fig. 247. Diagram of the flower of *Circæa.*——*Fig.* 248. Diagram of the flower of *Staphylea pinnata.*

In an isomerous flower the number of parts is indicated by a Greek numeral prefixed to the termination *-merous*. When there are two leaves in each whorl, as in *Circæa* (*fig.* 247), the flower is *dimerous*, and the symmetry is said to be *binary* or *two-membered*. This arrangement is indicated by the symbol 2/. When there are three parts in a whorl, as in the Lily, the flower is *trimerous*, and the symmetry is *ternary*, *trigonal*, or *triangular*; it is indicated thus, 3/. When there are four parts in a whorl, as frequently in the Rue (*fig.* 282), the flower is *tetramerous*, and the symmetry, which is marked $\sqrt[4]{}$, is *quaternary* or *tetragonal*. When there are five parts in a whorl, as in *Crassula rubens* (*fig.* 245), the flower is said to be *pentamerous*, and the symmetry, which is marked thus, $\sqrt[5]{}$, *quinary* or *pentagonal*.

Of the above arrangements, the pentamerous is most common among Dicotyledons, although the tetramerous is by no means rare; while the trimerous is generally found in Monocotyledons.

Although a symmetrical flower, as above described, necessarily implies that the parts of any whorl are equal to, or some multiple of those of all the others, botanists have generally agreed to call a flower symmetrical when the three outer whorls correspond in such particulars, while the parts of the gynæcium are unequal to them, as in *Staphylea pinnata* (*fig.* 284), where the three outer whorls are pentamerous, while the pistil is dimerous. The gynæcium, of all the organs of the flower, is that which least frequently corresponds in the number of its parts to the other whorls.

By most botanists, however, a flower is said to be symmetrical when it can be divided by any vertical section into two precisely similar halves, the different halves produced by every such section being exactly alike. Such flowers as those of the Lily, or *Crassula* (*fig.* 245), are instances of this symmetry. A flower which is symmetrical in this sense is also called *actinomorphic*. Flowers which can be divided by only one such section into two similar halves are called *zygomorphic*. Such flowers are found in the Aconite, the Pea, the Dead-nettle, &c. The line through which the section must pass to bring about the result is called the *plane of symmetry*; it may be antero-posterior, as in the flowers mentioned; or lateral, as in the Fumitory; or oblique, as in some members of the *Solanaceæ*. When a division into two similar halves is not possible by a section in any plane, the flower is said to be *asymmetrical*.

Various other terms are used in describing flowers, which will be best alluded to here. A flower is said to be *complete* when the four whorls—calyx, corolla, andrœcium, and gynæcium—are present, as in the Rue (*fig.* 282); when one or more of the whorls is absent, the flower is *incomplete* (*figs.* 255 and 256). When the parts of each whorl are uniform in size and shape, as in the Rue, the flower is *regular*; under other circumstances it is *irregular*, as in the Pea (*fig.* 303).

In a normal arrangement of the parts of the flower, the successive whorls alternate with each other, as shown in *fig.* 247;

the sepals are here alternate with the petals, the petals with the stamens, and the stamens with the carpels.

We have seen that, when the leaves of the vegetative branch are arranged in whorls, these whorls are developed in acropetal succession, and the leaves of any whorl arise in such a position as to stand over the intervals between the leaves of the whorl below it. As the flower is to be regarded as a modified branch with verticillate phyllotaxis, its parts should be arranged upon the same plan as those of the vegetative branches. The whorls being four, we can devise what may be called a typical flower, based upon this resemblance. Such a flower, therefore, should possess a calyx, corolla, andrœcium, and gynæcium, each of which should be so arranged that its parts form but a single whorl; the different whorls should consist of an equal number of members; the parts of successive whorls should alternate with one another; and the members of each should be uniform in size and shape, and distinct from each other and from the neighbouring whorls. This normal or typical flower is, however, liable to various alterations, arising from several disturbing causes, which modify and disguise one or more of its typical characters. Some of these causes have been already alluded to in the description of the different organs of the flower, but it will be necessary for us to investigate them more fully here, and classify them for systematic study.

The more important deviations of the flower from the typical character may be arranged under the following heads :—

1. Irregularity of form in the members of one or more of the whorls.
2. Multiplication of parts.
3. Suppression or abortion of a whorl or part of a whorl.
4. Displacement, or interference with the regular alternation of the whorls.
5. Coalescence of the parts or members of a whorl with one another.
6. Coalescence of the members of one whorl with those of another.
7. Substitution of spiral for whorled phyllotaxis.
8. Metamorphosis of parts of the flower.

1. *Irregularity of Form.*—This is most commonly seen in the perianth whorls. A sepal or a petal may develop a spur or prolongation downwards from its base, as in the Larkspur or the Indian Cress (*fig.* 295). If only one such structure is formed the flower becomes zygomorphic. A great variety of form of

both calyx and corolla is caused by unequal development of this kind, and it will be convenient to reserve a detailed examination of the most frequently occurring cases till we discuss these whorls in detail. Irregularity of this kind is also fairly common in the whorls of the sporophylls.

2. *Addition or Multiplication of Parts.*—This may be considered under two heads. 1st. The addition of one or more entire whorls in one or more of the floral cycles. 2nd. An increase in the number of parts of one or more whorls. The former is commonly called *augmentation*; the latter, *chorisis*, *deduplication*, or *unlining*.

a. *Augmentation.*—The increase in the number of whorls may occur in one or more of the floral cycles. The Barberry (*fig.* 249) has two whorls of sepals, two of petals, and two of stamens; in this flower, therefore, we have an addition of one whorl of members to each of the three external floral cycles. In the Poppy, we have a number of additional whorls of stamens (*fig.* 250).

FIG. 249.

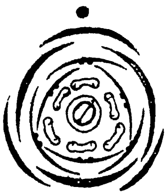


FIG. 250.

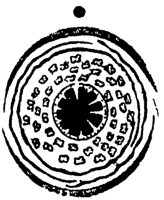


FIG. 251.

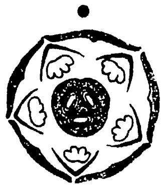


Fig. 249. Diagram of the flower of the Barberry (*Berberis*).——*Fig.* 250. Diagram of the flower of the Poppy (*Papaver*).——*Fig.* 251. Diagram of the flower of Buckthorn (*Rhamnus catharticus*).

The increase in the number of the whorls is most common among the stamens. Very frequently there is one extra whorl intercalated here, so that the stamens are twice as numerous as the sepals or petals. So constant is this occurrence in Monocotyledons that many botanists regard two whorls of stamens as a normal feature of that group. Such flowers are said to be *diplostemonous*, in contradistinction from those with one whorl, which are called *isostemonous*.

The new whorl generally falls into symmetrical position with the others, being alternate with the outer stamens on the one side and the carpels on the other. Sometimes, as in *Geraniaceæ* this alternation is not observed, and of the two whorls of stamens the outer is opposite to the petals. This condition is known as *obdiplostemony*. In such a flower the departure from typical symmetry, due to multiplication, is complicated by a further one of displacement.

A curious arrangement of augmented stamens is found in the flowers of some *Rosaceæ*. There are in two species of *Cratægus* ten stamens arranged in a single whorl; they are not exactly opposite the sepals and petals, as they should be, on the hypothesis of the addition of a whorl of five to the andrœcium, but stand in pairs opposite to the sepals. In *Nuttallia* a third whorl of five is added, which are opposite to the petals. In other species, additional whorls of five each are present, making as many as fifty stamens in some flowers.

b. *Chorisis or Deduplication.*—This is generally looked upon by botanists as another means of multiplication of the parts of a flower. It consists in the division or splitting of a member in the course of its development, so that two or more members are produced in the place of one. Chorisis differs from augmentation in the fact that it not only increases the number of parts, but also interferes with their regular alternation; for augmentation does not necessarily interfere with alternation, though it may obscure it when the number of additional parts is excessive, or when the whorls are crowded together.

Chorisis may take place in two ways: either transversely, when the increased parts are placed one before the other, which is called *vertical, parallel*, or *transverse chorisis*; or collaterally, when the increased parts stand side by side, which is termed *collateral chorisis*.

Transverse chorisis is supposed to be of frequent occurrence. The petals of *Lychnis* (*fig.* 327, *a*) and many other Caryophyllaceous plants exhibit a little scale on their inner surface at the point where the limb of the petal is united to the claw. A somewhat similar scale, although less developed, occurs at the base of the petals of some species of *Ranunculus* (*fig.* 324). The formation of these scales is supposed by many to be due to the chorisis or unlining of an inner portion of the petal from the outer. Each petal of *Parnassia* (*fig.* 326) has at its base a petal-like appendage divided into a number of parts, somewhat resembling sterile stamens; this also is considered to be produced by transverse chorisis.

In plants of the order *Rhamnaceæ* (*fig.* 251), and others, the stamens are placed opposite to the petals; hence they have been supposed by many botanists to be produced by chorisis from the corolla; but others explain this opposition of parts by supposing the suppression of an intermediate whorl. Transverse chorisis is frequently to be found in the andrœcium, but it is less frequent in the gynæcium. An example of transverse chorisis in the gynæcium is furnished, however, by *Crassula* (*fig.* 245), where each carpel has at its base on the outside a little greenish scale *a*, *a*, which is supposed by some to be due to it.

It will be observed that, in the above cases of transverse chorisis, the parts which are produced do not resemble those from which they arise, and this appears to be a universal law in this form of chorisis.

Collateral Chorisis.—We have a good example of this form

FIG. 252.

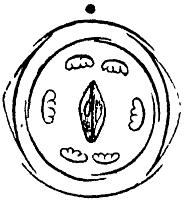


FIG. 253.

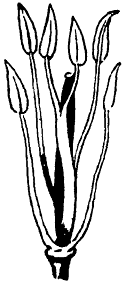


FIG. 254.

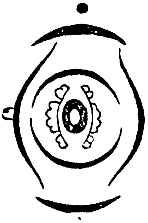


Fig. 252. Diagram of the flower of the common Wallflower.——*Fig.* 253. Flower of a species of *Streptanthus*, with the floral envelopes removed, showing a forked stamen in place of the two anterior stamens. From Gray.—*Fig.* 254. Diagram of the flower of the Fumitory.

in the Stock, Wallflower, and other plants of the order *Cruciferæ* (*fig.* 252). Within the perianth we find six stamens; of these, two form an outer whorl and stand opposite to the lateral sepals, while the other four are placed in pairs opposite the anterior and posterior sepals, forming an inner whorl; the latter has, therefore, four stamens instead of two, which result from the collateral chorisis of those two. This view is supported by the fact that in the genus *Streptanthus* (*fig.* 253), in place of the two stamens, as commonly observed, we have a single filament forked at the top, and each division bearing an anther, which would seem to arise from the process of chorisis being incompletely carried out. The flowers of the Fumitory are also generally considered to afford another example of collateral chorisis (*fig.* 254). In these we have two sepals, four petals in two rows, and six stamens, grouped together into two bundles or phalanges. The central one of each bundle bears a two-lobed anther, the lateral ones have only half an anther each. This has been held to arise from chorisis of two original stamens. It is possible, however, to regard each phalanx or bundle of stamens as corresponding to a ternate leaf, each lateral lobe of which bears two sporangia, while the central one bears four. It may be considered, indeed, that collateral chorisis is illustrated by the compound as compared with the simple leaf. It is evident that, on this hypothesis, collateral chorisis is only a form of branching of the staminal leaf. Other examples of this modification of the typical flower are by some considered to be afforded by the flowers of many species of *Hypericum* (*fig.* 265, *f*, *f*), in which each bundle of stamens is supposed to arise from the repeated chorisis of a single stamen. Each bundle may, however, be due to its branching rather than to its repeated division. The multiplication of the stamens of *Cratægus* already described (page 134) may be due to this form of chorisis.

FIG. 255.

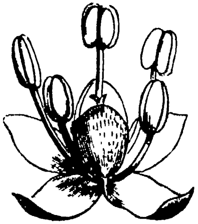


FIG. 256.

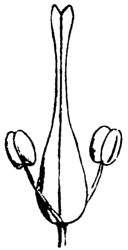


Fig. 255. Flower of Goosefoot (*Chenopodium*), with only one floral envelope (*monochlamydeous*).——*Fig.* 256. Flower of the common Ash (*Fraxinus*), in which both floral envelopes are absent (*achlamydeous*).

3. *Suppression or Abortion.*—The suppression or abortion of parts may either extend to entire whorls or be confined to one or more parts of a whorl.

a. *Suppression or Abortion of one or more Whorls.*—We have already stated that a complete flower is one which contains calyx, corolla, andrœcium, and gynæcium. When a whorl is suppressed, therefore, the flower necessarily becomes incomplete. This suppression may take place either in the *floral envelopes* or in the *sporophylls.*

Sometimes one whorl of the floral envelopes is suppressed, as in *Chenopodium* (*fig.* 255), in which case the flower is *apetalous* or *monochlamydeous*; sometimes both whorls are suppressed, as in the Ash (*fig.* 256), when the flower is *achlamydeous*.

When from such suppression only one perianth whorl is present, it is usual to speak of it as the calyx, though it may be petaloid or coloured, as in *Caltha* and *Anemone*. Its calycine nature in these cases can be determined by a comparative examination of other closely related flowers, as the Hellebore, where the true petals have undergone a curious change of form. In some cases the calyx appears absent, as in the Valerians and most *Umbelliferæ*. It is, however, only partly lost, being united throughout most of its length with the ovary, and only exposing a rim at the top of the latter.

FIG. 257.

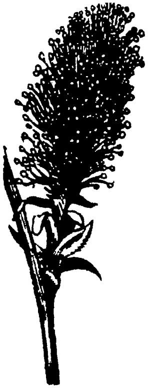


FIG. 258.

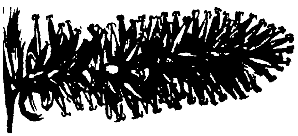


Fig. 257 Catkin of staminate flowers of a species of Willow (*Salix*).——*Fig.* 258 Catkin of pistillate or carpellary flowers of the same.

Suppression of a whorl of sporophylls is not uncommon; in such a case the flower is said to be *imperfect*. The andrœcium or gynæcium, or both, may be thus suppressed. When the stamens are abortive it is *pistillate* (*fig.* 258); when the pistil is absent it is *staminate* (*fig.* 257).

b. *Suppression of one or more Members of a Whorl.*—This is a very common cause of deviation from typical structure; we can here bring forward only a few examples.

This suppression of parts is most frequent in the gynæcium. In *Rhamnus* (*fig.* 251) we have five sepals, five petals, five stamens, and three carpels; here two carpels are suppressed. In the Pansy (*fig.* 259) we have again a pentamerous flower, so far as the calyx, corolla, and andrœcium are concerned, but only three carpels, two carpels being here suppressed; in Leguminous plants (*fig.* 260) we have five sepals, five petals, ten stamens, and only one carpel, four of the latter being here suppressed; in plants of the order *Compositæ* the calyx, corolla, and andrœcium have each commonly five members, but only two carpels are present.

In some species of *Impatiens* (*fig.* 261) we have five carpels, five stamens, and five petals, but only three sepals; here two sepals are suppressed; in *Tropæolum pentaphyllum* (*fig.* 262) there are five sepals, and but two petals, three of the latter being here abortive. In the *Labiatæ* and *Scrophulariaceæ* one of the stamens is commonly suppressed, and sometimes three; in *Lamium* we have five parts to both calyx and corolla, but only four stamens; and in *Salvia* we have also five parts to both calyx and corolla, but only two stamens.

FIG. 259. FIG. 260. FIG. 261.

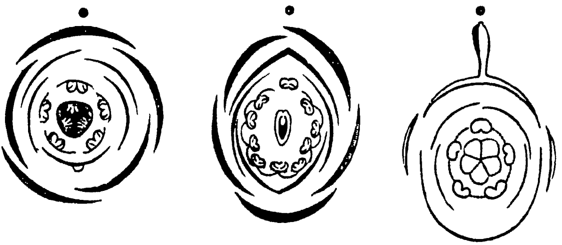


Fig. 259. Diagram of the flower of the Heartsease (*Viola*).——*Fig.* 260. Diagram of a Leguminous flower.——*Fig.* 261. Diagram of the flower of *Impatiens parviflora.*

FIG. 262.

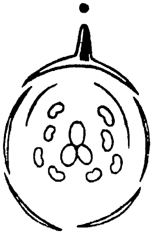


Fig. 262. Diagram of the flower of *Tropæolum pentaphyllum.*

Besides these examples of the suppression of parts, there is another kind of suppression, to which the term *abortion* more properly applies. This consists in the *degeneration* or *transformation* of the parts of a flower. In *Scrophularia* the fifth stamen is reduced to a scale; in the *Umbelliferæ* the limb of the calyx is commonly abortive, while in the *Compositæ* it is either abortive (*fig.* 291), or membranous (*fig.* 292), or reduced to the form of a number of hair-like growths known as a *pappus.*

Stamens which have undergone such degeneration are known as *staminodes*. The anther is usually replaced by a somewhat foliaceous expansion which has no pollen-sacs.

In some cases such degeneration is accompanied by an increase in the number of the members of other whorls. In cultivated semi-double flowers we frequently find both stamens and carpels partially replaced by petals, and the number of the latter considerably increased.

4. *Displacement.*—This results in the superposition of apparently successive whorls which in the typical flower are alternate with each other. In some cases it is only apparent, and is due to multiplication of the whorls, as in the Barberry already described. The result of the multiplication in the latter is that each petal has a stamen before and a sepal behind it (*fig.* 249).

In the Lily-of-the-valley there is a six-parted perianth, each lobe of which has a stamen in front of it. This is not due, however, to displacement. The perianth is the representative of two whorls of leaves which alternate with each other, and there are two whorls of stamens within the perianth, also regularly alternating. The flower being very small, the bases of all these leaves are crowded closely together, the two whorls of the perianth become completely fused into one, and the true relation of the parts can be detected only by careful examination and comparison with the flowers of other members of the same natural order.

In many cases, however, particularly in the corolla and andrœcium, the members of two succeeding whorls are superposed. Allusion has been made to such displacement in the case of the stamens of obdiplostemonous flowers, the outer whorl of which is superposed upon the petals, while the inner one stands opposite to the sepals. In several natural orders—*Plumbaginaceæ*, *Primulaceæ*, and *Rhamnaceæ*, for example—the stamens, which are isostemonous, stand each in front of a petal (*figs.* 251 and 263).

The anteposition is generally explained by the suppression of an external whorl of stamens between those remaining and the petals. Traces of these missing stamens are seen in some flowers; for instance, in some *Primulaceæ* there is found in this position in the flower a whorl of staminodes.

5. *Cohesion of Parts, or the Coalescence of the Members of the same Whorl.*—We have seen that in the typical flower the members of each whorl of floral leaves are distinct from each

other. This is, however, very frequently not the case; the calyx, instead of being evidently formed of a number of sepals appears like a more or less cup-shaped body with a number of teeth. The cup may be cleft nearly to the base, or the teeth may be very small and almost inconspicuous. The corolla, again, may be evidently detachable as a single structure. The teeth may be regular or irregular in size and shape, giving rise to many forms which will be described in detail later. The staminal whorl is less frequently affected by this coalescence, but it is extremely common in the pistil.

When a perianth whorl is made up of separate leaves it is said to be *polysepalous*, or *eleutherosepalous*, *eleutheropetalous*, &c. When the leaves are not free from each other, it is called *gamo-sepalous* or *-petalous*. When the stamens are united thus by their filaments, they are said to be *monadelphous*, as in the Mallow (*fig.* 264). Sometimes the apparent union does not include all the stamens, but these are gathered together into two or more bundles or phalanges, as in *Hypericum* (*fig.* 265).

FIG. 263.

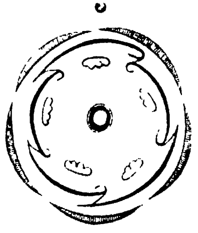


FIG. 264.

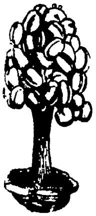


FIG. 265.

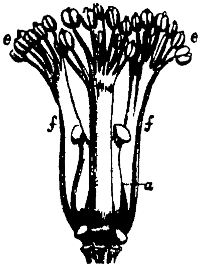


Fig 263. Diagram of the flower of a species of *Plumbago.*——*Fig.* 264. Monadelphous stamens of Malva.——*Fig.* 265. Triadelphous stamens of a species of *Hypericum*. *a*. Pistil. *f*. United filaments. *e*. Anthers.

A pistil whose carpels are distinct is said to be *apocarpous*, as in the Buttercup and Pheasant's-eye; one in which they are united is called *syncarpous*, as in the Lily. The union may be confined to the ovary, or may extend to the style and stigma.

Sometimes the coalescence of the members of the whorl involves also those of the next whorl above it. In the Lily-of-the-valley both perianth whorls, which were originally alternate with each other, have all coalesced into a six-toothed bell, appearing like a gamopetalous corolla. These are said to be *gamophyllous*.

In *Rosa*, *Potentilla*, and a few other plants of the same family, the cohesion of the sepals is still more complicated by the fact that each sepal is stipulate, and the stipules also are coalesced into what resembles a whorl of bracts below the calyx (*fig.* 267). This is known as an *epicalyx*; it must not be confused with the epicalyx of the Mallow, which has a different origin, as already described.

Though the term *cohesion* has been used to describe this coalescence, it must not be supposed that parts originally free have become united. The young leaves originate on the thalamus as separate outgrowths, but the apical growth soon stops, and basal growth leads to the outgrowth of the whole annular zone of the young receptacle on which the leaves have appeared. This zone is really composed of the bases of the separate leaves, which are developed thus together, much as are the wings of the separate branches of the epipodium of a pinnatifid leaf.

FIG. 266.

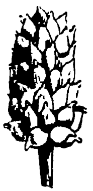


FIG. 267.

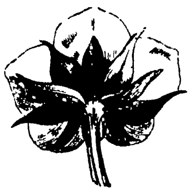


FIG. 268.

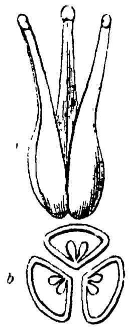


FIG. 269.

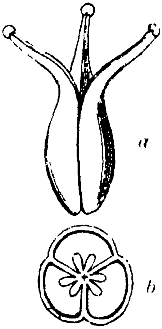


Fig. 266. Apocarpous pistil of the Pheasant's-eye (*Adonis* *Fig.* 267. Flower of Strawberry, with stipular epicalyx.—*Fig.* 268. *a*. Diagram of three carpels, placed side by side, but not united. *b*. A transverse section of the ovaries of the same.—*Fig.* 269. *a*. Diagram of three carpels united by their ovaries, the styles and stigmas being free. *b*. A transverse section of the ovaries of the same.

A few cases of true cohesion of parts originally free are met with. In *Asclepias* the stigmas cohere together and to the anthers of the flower. In a species of *Lonicera* the ovaries of two opposite flowers of an inflorescence unite to form connate fruit.

Where the stamens of a flower are gathered into several bundles, as in *Hypericum*, the condition is probably due to the branching of a corresponding number of original protuberances.

Other cases of cohesion will be referred to later.

6. *Adhesion of Parts, or Coalescence of the Members of one Whorl with those of another.*—This again is a very common disturbance. Normally, the several whorls are placed upon the thalamus in such a way that their acropetal order of succession can be recognised. The ovary stands at the apex of the thalamus, and is said to be *superior*. The calyx is as evidently the lowest whorl, and is termed *inferior*. The corolla and stamens springing from below the ovary are said to be *hypogynous* (*fig.* 270).

FIG. 270.

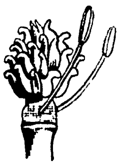


FIG. 271.

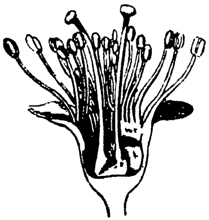


FIG. 272.

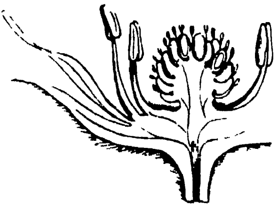


Fig. 270. Hypogynous stamens of Buttercup.—*Fig.* 271. Perigynous stamens of Cherry. —*Fig.* 272. Perigynous flower of Strawberry.

Often, however, the base of the calyx seems to be spread out into a sort of cup, and the petals and stamens appear to spring from it at a little distance from the thalamus. The corolla and stamens are then said to be *perigynous* (*figs.* 271 and 272). The cup bearing the stamens and petals may grow completely over and become fused with the wall of the ovary; the latter is then said to be *inferior*, and the corolla and stamens are *epigynous* (*fig.* 273). Though such a pistil appears to bear the other whorls upon its apex, this is not really the case; it is always the terminal whorl.

The cup appears to be the dilated base of the calyx, but this appearance is misleading. It is really the thalamus which has become concave, and the fused calyx leaves grow from it as do the petals and stamens.

The true interpretation of the structure of the inferior ovary depends upon a proper appreciation of the change in form of the thalamus. In some cases it arises from the early suppression of the apical growth of the latter and the continuation of the development of its peripheral tissue, which thus rises as an annular zone or cup. On the margin of this cup are developed successively the perianth and stamens. The carpels are developed at the true apex of the thalamus, and therefore at the bottom of the cup, and their walls are fused with the interior of the receptacular cup as development continues. The outer wall of the ovary is so formed of the hollowed-out thalamus or receptacle. This view of its origin is supported by the fact that in some cases the ovary of the Gooseberry is found to have one or two small foliage leaves springing from it, indicating the axial nature of the outer wall.

FIG. 273.

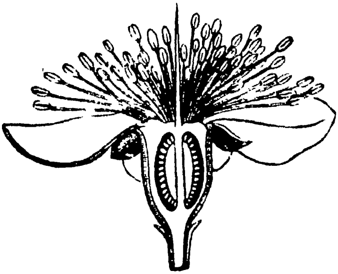


FIG. 274.

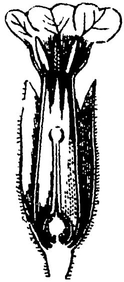


Fig. 273. Epigynous flower of Myrtle.—*Fig* 274. Epipetalous stamens of Primrose.

In other cases the apex of the thalamus does not cease growing, but takes part in the concave growth. The carpels consequently arise at the top of the cup, closing it in and growing downwards into its cavity.

Adhesion between the stamens and petals is very common. It is generally associated with cohesion in the corolla, and is accounted for by the outgrowth from the receptacle of an annular zone from which spring both petals and stamens. These arise from it by apical growth at first, but this is soon replaced by basal as before described, and the whole of the bases of the two whorls are so developed as a single band of tissue. The origin is thus comparable to the fusion of all the perianth leaves in the Lily-of-the-valley already described. Such an arrangement of stamens is called *epipetalous* (*fig.* 274).

FIG. 275.

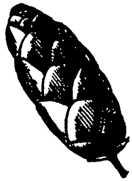


Fig. 275. Cone of Hemlock Spruce (*Pinus canadensis*).

7. *Spiral Phyllotaxis.*—In the Gymnosperms both staminate and pistillate flowers have frequently this form of phyllotaxis. Good instances are afforded by the so-called *cones* of many genera, which were formerly regarded as inflorescences. These structures constitute the pistillate flowers of such forms as *Pinus*, *Abies*, &c. (*fig.* 275). Each consists of a woody axis on which the sporophylls are arranged in a close spiral. Each sporophyll is at first succulent, but ultimately becomes hard and woody. It bears on its upper surface a large scale-like outgrowth or placenta, and at the base of the latter there are two ovules. Similar cones occur among the Cycads, some of which have both microsporophylls and megasporophylls so arranged. Spiral phyllotaxis also occurs in the Angiosperms in certain families where the normal phyllotaxis of the flower is whorled, though it is less common than the other cases of interference with typical symmetry. There are two degrees in which it exists. *a.* The whole of the floral leaves may be arranged spirally, as in the Water-lily (*Nymphæa*) (*fig.* 276). Here the members of the separate whorls show gradual transition from one form to the

FIG. 276.

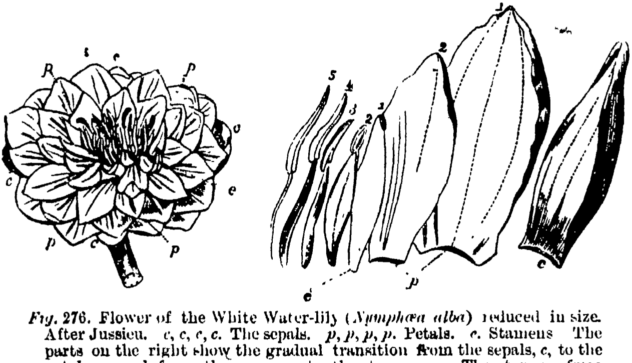


Fig. 276. Flower of the White Water-lily (*Nymphæa alba*) reduced in size. After Jussieu. *c, c, c, c.* The sepals. *p, p, p, p.* Petals. *e.* Stamens The parts on the right show the gradual transition from the sepals, *c*, to the petals, *p*, and from these organs to the stamens, *e*. The stamens from 1 to 5 are gradually more distinctive.

next. The outer leaves are green and sepaloid; as we pass inwards their green hue is gradually replaced by white, till they are evident petals; there is a similar transition from petals to stamens, the leaves becoming narrower and indications of anthers appearing at their summits, till the definite staminal form is reached. Such flowers are known as *acyclic*. *b.* The perianth may be in whorls and the sporophylls arranged spirally. This is the case in some of the Buttercups, where there are two series of spirals, the andrœcium and gynæcium. They do not show a transition to each other as in the former case. Such a flower is termed *hemicyclic*. Sometimes the whorls of the perianth are not true ones, but result from a condensed spiral. This may be seen in such corollas as have a quincuncial æstivation (see page 205).

8. *Metamorphosis of Parts of the Flower.*—A modification of the structure of the flower, which is not uncommon, is seen in cases where one leaf or more of either of the whorls have assumed an abnormal appearance or structure. In the Aconite the petals are developed as two long slender bodies with a dilated head, which stand together under the arched upper sepal (*fig.* 277). In the Hellebore all the petals are represented by small tubular bodies which are nectaries. In some flowers again, particularly in cultivated forms, we meet with cases where leaves of the andrœcium are developed as petals. This is most generally found in flowers which have typically many stamens, *e.g.* Roses, Buttercups, &c. We have as a result so-called *double flowers*. Occasionally such a metamorphosis occurs in wild flowers.

FIG. 277.

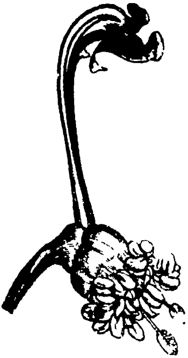


Fig. 277. A portion of the flower of the Monkshood (*Aconitum*), with numerous stamens below, and two stalked somewhat horn-shaped petals above.

Other forms of interference with normal symmetry are due to modification of the floral axis or thalamus. These will be discussed later. Sometimes a flower which is normally zygomorphic, from a single petal being spurred, becomes regular by developing spurs to all its petals. Such a flower is called *peloric*.

THE PARTS OF THE FLOWER.

We must now examine the structure of the flower in greater detail, dealing with the axis and its modifications, and with the peculiarities of the separate floral whorls.

(1) THE THALAMUS.

The part of the flower-stalk or axis which is above the insertion of the leaves of the calyx, and so is within the flower, has been variously distinguished by botanists as the *thalamus*, *receptacle*, and *torus*.

In the majority of plants it consists of three undeveloped internodes, and accordingly presents no remarkable feature; but in others it becomes much enlarged, and then assumes a variety of appearances, and modifies to a considerable extent the form of the flower. In the species of *Magnolia*, *Liriodendron*, and plants of the order *Magnoliaceæ* generally, the thalamus is cylindrical (*fig.* 407, *a*); in plants also of the order *Anonaceæ* it usually acquires a somewhat similar form; in the Raspberry (*fig.* 409, *l*) and species of *Ranunculus* (*fig.* 270) it is conical; in the Strawberry (*fig.* 272) hemispherical; in *Nelumbium* (*fig.* 278, *thal*) it is a large tabular expansion in which there are a number of cavities containing the separate carpels. In the Rose it forms a deep cup, upon the sides of which the carpels are placed (*fig.* 285, *r*, *r*).

In the *Primulaceæ*, *Santalaceæ*, and in all cases where the ovules are not developed upon the carpellary leaves, the thalamus becomes prolonged into the cavity of the ovary and bears the *placenta* (*fig.* 438). At other times the thalamus becomes prolonged beyond the ovary, as in the *Geraniaceæ* and *Umbelliferæ*; this prolongation is termed a *carpophore*. In the species of *Geranium* (*fig.* 443, *c*), this carpophore forms a long beak-like process, to which the carpels, *car*, are attached, and from which they separate when the fruit is ripe. In many cultivated flowers, as in the Rose, the thalamus sometimes acquires a monstrous development, and becomes extended beyond the flower into a branch bearing foliage leaves (*fig.* 279). To this prolongation of the axis beyond the flower the term *median prolification* is usually applied.

In some plants the last internode of the thalamus becomes elongated and forms a stalk to the ovary, to which the term *gynophore* has been applied; sometimes the internode between the perianth and the sporophylls elongates. Examples may be seen in some of the *Capparidaceæ* (*fig.* 280 *thal*); in the Pink (*fig.* 405, *g*), *Dictamnus* (*fig.* 427, *g*), and *Xanthoxylon* (*fig.* 411, *g*).

Sometimes the thalamus presents certain modifications of form which are seen between the floral whorls. They are due to changes in particular internodes, and generally occur above the perianth leaves. Any such modification of the thalamus is known as the *disc*. Under this term we include all bodies, of whatever form, except sporophylls, which are situated on the

FIG. 278.

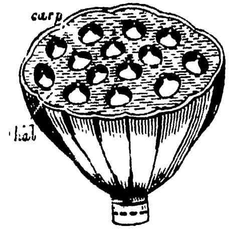


FIG. 279.

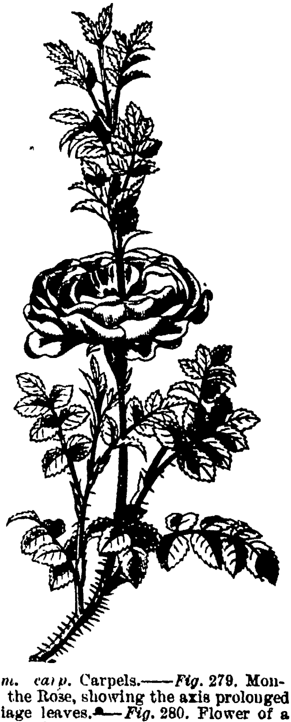


FIG. 280.

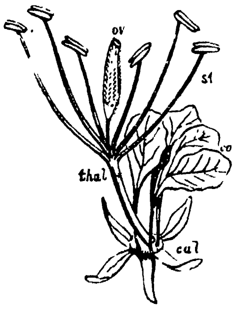


Fig. 278. *thal.* Thalamus of *Nelumbium.* *carp.* Carpels.——*Fig.* 279. Monstrous development of the flower of the Rose, showing the axis prolonged beyond the flower and bearing foliage leaves.——*Fig.* 280. Flower of a species of *Gynandropsis*, belonging to Capparidaceæ. *cal.* Calyx. *cor.* Corolla. *thal.* Prolonged thalamus or gynophore, supporting the stamens, *st*, and ovary, *ov*.

thalamus between the calyx and gynæcium, or which are upon or in connection with either of these organs, but which cannot be properly referred to them.

The disc is developed in a variety of forms; in the Orange and Rue (*fig.* 282) it forms a fleshy ring surrounding the base of the pistil; in the Tree Pæony (*fig.* 283) it occurs as a dark red cup-shaped expansion covering nearly the whole of the pistil except the stigmas; in the Cherry (*fig.* 271) it forms a sort of waxy lining to the receptacular tube. In other cases the disc is represented by little separate glandular bodies, as in some Cruciferous plants; or by scales, as in the Stonecrop (*fig.* 284) and Vine (*fig.* 344); or by various petaloid expansions, as in the Columbine.

FIG. 281.

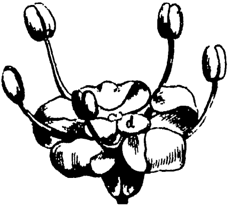


FIG. 282.

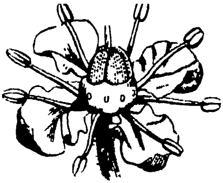


Fig. 281. Flower of the Fennel (*Fœniculum capillaceum*). The ovary is surmounted by a disc, *d*.——*Fig.* 282. Flower of the Rue (*Ruta graveolens*). The pistil is surrounded by a disc in the form of a fleshy hypogynous ring, on the outside of which the stamens are inserted.

FIG. 283.

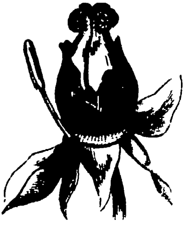


FIG. 284.

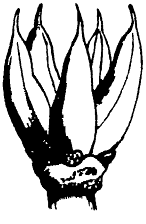


Fig. 283. Pistil of the Tree Pæony (*Pæonia Moutan* or *Moutan officinalis*) invested by a large cup-shaped expansion or disc.——*Fig.* 284. Pistil of Stonecrop (*Sedum*), consisting of five distinct carpels, on the outside of each of which at the base a small scaly body may be noticed. The pistil is compound and apocarpous.

A peculiar swelling upon the summit of the inferior ovaries of the flower of the Natural Order *Umbelliferæ* is also generally referred to as a variety of the disc, though it is above instead of below the gynæcium. It forms a conical swelling which surrounds and adheres to the bases of the two divaricating styles. On this account it is sometimes called a *stylopodium*.

The disc is termed *hypogynous*, *perigynous*, or *epigynous*, according to its position with reference to the ovary.

(2) THE WHORLS OF PERIANTH LEAVES.

a. *The Calyx.*

The calyx is the outermost envelope of the flower, and is composed of two or more leafy members called *sepals*. These sepals are usually green like the foliage leaves, by which character they may, in most cases, be distinguished from the petals, as well as by the position and more delicate texture of the latter. There are numerous instances, however, especially when the number of petals is much increased, in which there is a gradual transition from the sepals to the petals, so that it is difficult or almost impossible to say, in many cases, where the calyx ends and the corolla begins. The White Water-lily (*fig.* 276) affords a familiar and good illustration of this. In some plants, again, the green colour disappears, and the calyx becomes coloured with the same tints as the corolla, or with some other bright hues. In such cases it is said to be *petaloid*, and the chief distinctive character between it and the corolla is then afforded by its position on the outside of the latter organ. The Fuchsia, Indian Cress, Columbine, Larkspur, and Monkshood may be mentioned as affording familiar examples of a petaloid calyx amongst Dicotyledons. In Monocotyledons generally, as in the Lily, Iris, Tulip, Crocus, and Squill, the two floral envelopes, although sometimes green, are usually coloured and resemble each other so closely in other respects that the collective name of *perianth* is used to indicate the two whorls taken together. When there is but one whorl of floral envelopes, as in the Goosefoot (*fig.* 255), it is customary to call this the calyx, whether it is coloured or green.

In their structure, venation, and characters generally, the sepals resemble the foliage leaves. They exhibit various characters as regards their figure, margins, apex, &c., although they are by no means liable to such numerous variations in these particulars as are the blades of foliage leaves. The terms used in defining these modifications are the same as those applied to the blades of leaves.

Sepals are almost without exception destitute of a stalk, or, in other words, they are sessile upon the thalamus. They are also generally entire at their margins, although exceptions to this latter character occasionally occur: in the Pæony and Rose (*figs.* 285, *cf*, and 302, *cf*) the sepals are incised; in many species of Dock they are toothed; in *Chamælaucium plumosum* each sepal is divided into five deep lobes or partitions; and in *Passiflora fœtida* the sepals are pinnatisected, and each segment is pinnatifid.

The sepals may be either distinct from each other, as in the Poppy, Buttercup, Wallflower, and Strawberry (*fig.* 267); or more or less united into one body, as in the Pimpernel (*fig.* 287), Campion, and Henbane (*fig.* 288). In the former case the calyx is usually termed *polysepalous*, or *dialysepalous*; in the latter it is commonly called *gamosepalous*.

FIG. 285.

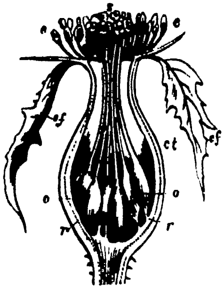


FIG. 286.

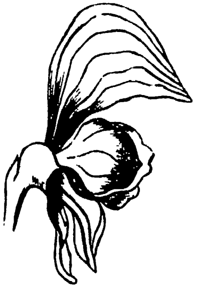


Fig. 285. Vertical section of the flower of the Rose. *r*, *r*. Concave thalamus, upon which are placed several carpels, *o*, *o*, each of which is furnished with a style and stigma, *s*. *e*, *e*. Stamens.——*Fig.* 286. Flower of Monkshood (*Aconitum Napellus*), with an irregular polysepalous calyx. The upper sepal is hooded or helmet-shaped.

1. POLYSEPALOUS OR DIALYSEPALOUS CALYX.—A polysepalous calyx may consist of two or more parts; the number is then indicated by a prefix of Greek numerals; it is *disepalous* when it is composed of two distinct sepals, *trisepalous* when it has three, and so on.

A polysepalous calyx is called *regular* if it consists of sepals of equal size and similar form, and is arranged in a symmetrical manner, as in the species of *Ranunculus* (*fig.* 227); and it is said to be *irregular* when the sepals vary in these particulars, as in the Monkshood (*fig.* 286).

2. GAMOSEPALOUS CALYX.—When the sepals are united so as to form a gamosepalous calyx, various terms are used to indicate the different degrees of fusion. The union may involve only the base of the leaves, as in the Pimpernel (*fig.* 287), when the calyx is said to be *partite*; or it may extend to about the middle, as in the Centaury, when it is *cleft* or *fissured*; or the sepals may be united almost to the top, as in the Campion, when it is *toothed*; or the union may be quite complete, when it is *entire*. The number of partitions, fissures, or teeth is indicated by the same prefixes as those previously referred to as used in describing the divisions in the lamina of a leaf, and in the majority of cases it corresponds to that of the component sepals of which the calyx is formed; although exceptions to this rule sometimes occur, as for instance in those cases where the divisions are themselves divided into others. A little care in the examination will, however, generally enable the observer to distinguish the primary from the secondary divisions. When a gamosepalous calyx is entire, the number of sepals can then be ascertained by the venation, as the principal veins from which the others diverge generally correspond to the midribs of the component sepals. In a gamosepalous calyx in which the union

FIG. 287.

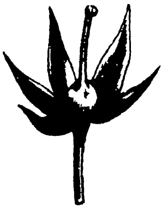


FIG. 288.

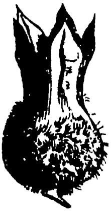


FIG. 289.

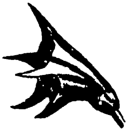


Fig. 287 Partite inferior calyx of the Pimpernel (*Anagallis*).—— *Fig.* 288. Urceolate calyx of the Henbane (*Hyoscyamus*).——*Fig.* 289. Bilabiate calyx of the Dead-nettle (*Lamium*).

FIG. 290.

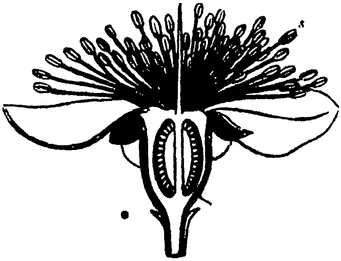


Fig. 290. Vertical section of the flower of the Myrtle (*Myrtus communis*). *cal.* Tube of the calyx adherent to the ovary, *o.* *s.* Stamens.

exists in a marked degree, the part where the sepals are united is called the *tube*, the free portion the *limb*, and the orifice of the tube the *throat* or *faux* (*figs*. 288 and 289).

If the union between the sepals is unequal, or the parts are of different sizes, or of irregular figures or forms, the calyx is said to be *irregular* (*fig*. 289); if, on the contrary, the parts are alike in figure and form, of the same size, and united so as to form a symmetrical body, it is *regular* (*fig*. 288). Some varieties of the irregular and also of the regular calyx have received special names. In the Dead-nettle (*fig*. 289), the irregular calyx is said to be *labiate*, *bilabiate*, or *lipped*, because the five sepals of which it is composed are united in such a manner as to form two lips. Of the regular forms of the gamosepalous calyx a number are distinguished under the names of *tubular*, *bell-shaped* or *campanulate*, *urceolate* (*fig*. 288), *conical*, *globose*, &c. The application of these terms will be further shown when speaking of the corolla, in which similar forms occur, and in which they are usually more evident.

FIG. 291.

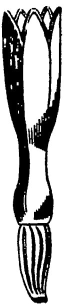


FIG. 292.

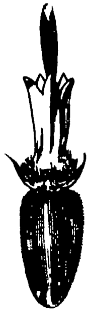


FIG. 293.

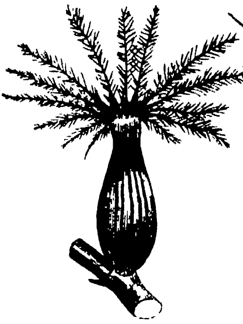


FIG. 294.

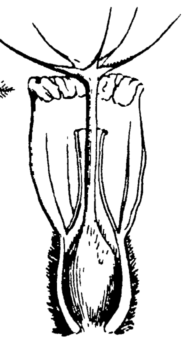


Fig. 291. One of the tubular florets of the Ox-eye (*Chrysanthemum*). The calyx is completely united to the ovary and presents no appearance of a limb.——*Fig*. 292. One of the tubular florets of the Sunflower (*Helianthus*). The limb of the adherent calyx is membranous.——*Fig*. 293. Fruit of the Valerian surmounted by a feathery sessile pappus.——*Fig*. 294. Fruit of Scabious surmounted by a stalked pilose pappus.

The tube of a gamosepalous calyx, or of that of a perianth (the parts of which, like the sepals, are frequently united to a varying extent), sometimes adheres more or less to the ovary, as in the Iris, Myrtle (*fig*. 290, *cal*), in all the plants of the order *Compositæ* and in those allied to it (*figs*. 291 and 292), and in numerous other plants. When this takes place, the calyx is said to be *adherent*, or, because it appears to rise from the summit of the ovary, *superior*;

the ovary in such a case is then described as *inferior*. When the calyx is free, or quite distinct from the walls of the ovary, as in the Pimpernel (*fig.* 287), Wallflower, and Poppy, or from the free carpels, as in the Buttercup, it is said to be *free*, *non-adherent*, or *inferior*; and the pistil is then termed *superior*.

When the calyx or perianth is adherent to the ovary, its limb presents various modifications: in the Iris, Crocus, and Orchids, it is *petaloid*; in the Quince, *foliaceous* (*fig.* 299); in the Sunflower (*fig.* 292) and Chamomile it is *membranous*; in the Madder it exists only in the form of a circular rim; while in the Ox-eye it is altogether absent (*fig.* 291). In the two latter cases the calyx is commonly described as *obsolete*. In many plants of the order *Compositæ* and the allied orders *Dipsaceæ* and *Valerianaceæ*, the limb of the calyx is only developed in the form of a circle or tuft of bristles, hairs, or feathery processes, to which the name of *pappus* is given, and the calyx under such circumstances is said to be *pappose*. The pappus is further described as *feathery* or *plumose*, and *simple* or *pilose*; it is *feathery*, as in the Valerian (*fig.* 293), when each of its divisions is covered on the sides by little hair-like projections arranged like the barbs of a feather; and *pilose* when the divisions have no marked projections from their sides, as in the Dandelion and Scabious (*fig.* 294). The pappus is also described as *sessile* when it arises immediately from the tube of the adherent calyx, and thus apparently from the top of the ovary or fruit, as in the Valerian (*fig.* 293); and *stalked* or *stipitate*, if it is raised above the ovary or fruit, on a stalk, as in the Dandelion and Scabious (*fig.* 294).

FIG. 295.

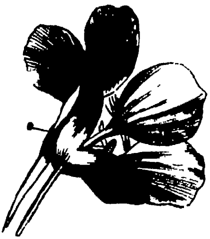


FIG. 296.

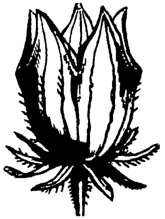


Fig. 295. Flower of the Indian Cress (*Tropæolum*). *c.* Spurred calyx. *Fig.* 296. Calyx of *Hibiscus* surrounded by an epicalyx or involucre.

MODIFICATIONS AND APPENDAGES OF THE CALYX.—The calyx, whether gamosepalous or polysepalous, is subject to various other irregularities besides those already alluded to, which arise from the expansion or growing outwards of one or more of the sepals or the tube into appendages or processes of different kinds.

In the Monkshood (*fig.* 286) the superior sepal is prolonged upwards into a sort of hood or helmet-shaped process, and is said consequently to be *hooded*, *helmet-shaped*, or *galeate*. In the Wallflower, and other plants of the *Cruciferæ*, the two lateral sepals are expanded on one side at the base into little sacs or pouches, and are termed *gibbous* or *saccate*. If the calyx has one or more tubular prolongations downwards, it is said to be *spurred*. Only one spur may be present, as in the Indian Cress (*fig.* 295, *c*), where the spur is formed by three sepals; or in the Larkspur, where it is formed by one; or each of the sepals may be spurred. In *Pelargonium* the spur, instead of being free from the pedicel as in the above instances, is adherent to it.

On the outside of the calyx of some flowers, as in those of many plants of the *Malvaceæ* (*fig.* 296), *Caryophyllaceæ* (*fig.* 300, *b*), and *Rosaceæ* (*fig.* 267), there is placed a whorl of leaf-like organs which is considered by some botanists as an outer calyx, and to which the name of *epicalyx* or *calyculus* has accordingly been given. The true nature of this outer whorl in the several cases has already been discussed.

FIG. 297.

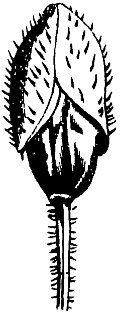


FIG. 298.

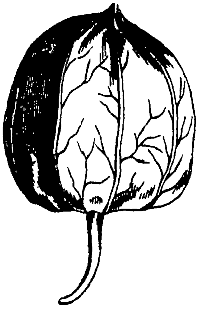


FIG. 299.

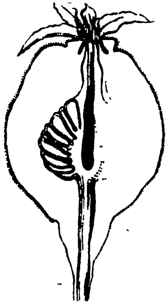


Fig. 297. Flower of the Poppy, showing a caducous calyx.——*Fig.* 298. Accrescent calyx of the Winter Cherry (*Physalis Alkekengi*).——*Fig.* 299. Vertical section of the fruit of the Quince (*Pyrus Cydonia*), showing the tube of the calyx adherent to the matured carpels, and forming a part of the pericarp: the free portion or limb being foliaceous.

DURATION OF THE CALYX.—The duration of the calyx varies in different flowers. It is *caducous* or *fugacious* when it falls off as the flower expands, as in the Poppy (*fig.* 297). In *Eschscholtzia* the calyx, which is caducous, separates from the hollow thalamus to which it is articulated, in the form of a funnel, or the extinguisher of a candle. A somewhat similar separation of the calyx occurs in *Eucalyptus*, except that here the part which is left behind after the separation of the upper portion evidently belongs to the calyx, instead of to the thalamus, as in the former instance. In these two latter cases the calyx is said to be *calyptrate* or *operculate*. When the calyx falls off at about the same time as the corolla, as in the Crowfoot or Buttercup, it is called *deciduous*. In other cases the calyx remains after the flowering is over, as in the Henbane (*fig.* 288) and Mallow, when it is described as *persistent*. When the calyx is adherent or superior it is necessarily *persistent*, and forms a part of the fruit, as in the Quince (*fig.* 299), Apple, Pear, Melon, and Cucumber. When it is persistent and assumes a shrivelled or withered appearance, it is said to be *marcescent*; when it is persistent, and continues to grow after the corolla has fallen off, so as to form a bladdery expansion round the fruit, as in the Winter Cherry and other species of *Physalis* (*fig.* 298), it is termed *accrescent*.

b. *The Corolla.*

The corolla is the inner envelope of the flower. It consists usually of a single whorl of leaves, called *petas*. In a complete, flow (*fig.* 245 *p*) it is situated between the calyx and andrœcium, and is generally to be distinguished from the former, as we have already seen, by its coloured nature and more delicate structure. When there is but one whorl of perianth leaves, as we have also before noticed, this is to be considered as the calyx, and the flower is then termed *apetalous* or *monochlamydeous*. The corolla is usually the most showy and conspicuous part of the flower; in some rare cases, however, it is green like the calyx, as in certain members of the Natural Order *Asclepiadaceæ*. The fragrance of a flower is associated with its petals.

The corolla is sometimes smooth, but very frequently its surface bears hairs of various forms and colours, particularly in those flowers which are pollinated by insects. Petals are frequently narrowed below into a stalk-like portion, which corresponds to the petiole of the leaf, as in the Wallflower and Pink (*fig.* 301); the narrow portion is then termed the *unguis* or *claw*, *o*, and the expanded portion the *limb*, *l*, and the petal is said to be *unguiculate* or *clawed*. In this particular, petals must be considered to resemble the foliage leaves more than the sepals do, as the latter organs are almost without exception *sessile*, or destitute of claws.

The shapes of the petals, like those of the sepals and leaves, are subject to great variation. They may be *linear*, *oblong*, *lanceolate*, *elliptic*, *ovate*, *cordate*, &c. The application of these terms, having been already fully explained when speaking of leaves, need not be further alluded to. The condition of their margins also, the manner in which they are divided, and their terminations, are also indicated by the same terms as those which we have already made use of in describing foliage leaves. The petals may be *dentate*, *serrate*, *cleft*, *partite*, *-sected*, *acute*, *emarginate*, &c. One particular condition of the margins does not occur in the case of the leaves; their edges are somewhat deeply slashed or divided, so as to present a number of long, narrow, almost thread-like processes. When this is the case the petals are said to be *fimbriated* or *fringed*. The condition is seen in some species of *Dianthus* (*figs.* 300 and 301).

FIG. 300.

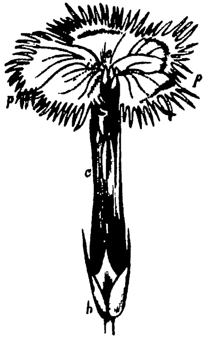


FIG. 301.

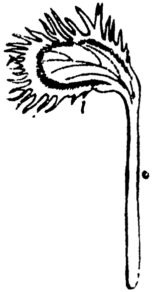


Fig. 300. The flower of a species of Pink (*Dianthus*). *b.* Bracts, forming an epicalyx or involucre. *c.* Calyx. *p, p.* Petals, the limbs of which are fringed at their margins. *e.* Stamens.——*Fig.* 301. One of the petals of the same flower. *o.* Claw or unguis. *l.* Limb, which is fringed at the margins.

In texture the petals are commonly soft and delicate, but they sometimes differ widely from this, and become thick and fleshy, as in the *Stapelias*; or dry and membranous, as in the Heaths; or stiff and hard, as in *Xylopia*.

The petals also, like the sepals, may be either distinct or more or less united into one body. In the former case, the corolla is said to be *polypetalous* or *dialypetalous* (*figs.* 300–303); in the latter, *gamopetalous* (*figs.* 304–321).

1. POLYPETALOUS OR DIALYPETALOUS COROLLA.—The number of petals which enter into the composition of the corolla is expressed, as in the case of the polysepalous calyx, by a prefix of the Greek

numerals. A corolla of two petals is said to be *dipetalous*; of three, *tripetalous*; and so on.

When the petals are all of the same size and of similar form, and are arranged in a symmetrical manner, the corolla is termed *regular*, as in the *Rosaceæ* (*figs.* 267 and 302); but when the petals vary in these particulars, as in the Pea and allied plants (*figs.* 260 and 303), it is said to be *irregular*. Several varieties of regular and irregular polypetalous corollas occur.

A. *Regular Polypetalous Corollas.*—Of these there are three characteristic forms, viz. the *cruciform* or *cruciate*; the *caryophyllaceous*; and the *rosaceous*.

1. *Cruciform or Cruciate.*—This corolla gives the name to the natural order *Cruciferæ*; but it also occurs elsewhere. It consists of four petals, usually with claws, as in the Wallflower and Stock; but sometimes without claws, as in the Celandine, and the whole arranged in the form of a cross.

FIG. 302.

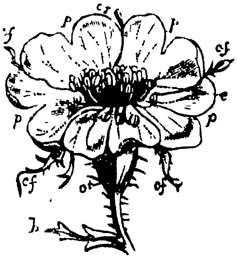


FIG. 303.

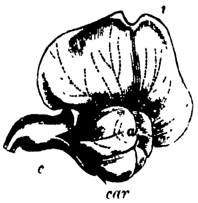


FIG. 304.

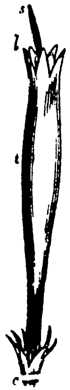


Fig. 302. Flower of the Rose. *b.* Bract. *ct.* Tube of the calyx. *cf, cf, cf, cf, cf.* Divisions of the calyx. *p, p, p, p, p.* Petals.——*Fig.* 303. The flower of the Sweet Pea (*Lathyrus odoratus*). *c.* Calyx. *v.* Vexillum. *a.* Alæ or wings. *car.* Carina or keel.——*Fig.* 304. Flower of *Spigelia marylandica*. *c.* Calyx. *t.* Tubular corolla. *l* Limb of the corolla. *s.* Summit of the style and stigmas.

2. *Caryophyllaceous.*—This consists of five petals, with long claws enclosed in the tube of the calyx, and with their limbs commonly placed at right angles to the claws, as in the Campion, Single Pink (*figs.* 300 and 301), and Carnation.

3. *Rosaceous.*—This is composed of five petals, which are sessile or have very short claws. They are concave above, and spread regularly outwards, as in the Strawberry (*fig.* 267) and Single Rose (*fig.* 302).

B. *Irregular Polypetalous Corollas.*—There are many anomalous forms of irregular polypetalous corollas to which no particular names are applied. There is one, however, namely the *Papilionaceous*, which is of considerable importance, as it occurs in all British *Leguminosæ*. It is composed of five petals (*figs.* 303 and 464) one of which is superior or posterior, and commonly larger than the others, and is termed the *vexillum* or *standard* (*fig.* 303, *v*); two inferior or anterior, which are usually more or less united and form a somewhat boat-shaped cavity, *car.*, called the *keel* or *carina*; and two lateral, *a*, called the *wings* or *alæ*. The alæ overlap the carina, and are themselves overlapped by the vexillum.

In many cases where a number of regular flowers are massed together, as in certain corymbs, umbels, or capitula, the flowers round the margin of the inflorescence become irregular by the greater development of such of their petals as are outermost. These are known as *radiant* flowers.

2. GAMOPETALOUS COROLLA. When the petals form a gamopetalous corolla, the same terms are used as in the case of the gamosepalous calyx to indicate the degrees of cohesion.

The gamopetalous corolla, like the gamosepalous calyx, is *regular* when its parts are of the same size, and of similar figure or form, and united so as to form a symmetrical body (*figs.* 304-309); otherwise, it is *irregular* (*figs.* 310–321).

A. *Regular Gamopetalous Corollas.*--The following forms are those most commonly occurring:—

1. *Tubular*, where it is nearly cylindrical throughout, the limb not spreading, as in *Spigelia* (*fig.* 304), and in the central florets of many *Compositæ*, as in the Ox-eye (*Chrysanthemum*) and Sunflower (*Helianthus*) (*fig.* 292).

2. *Campanulate* or *bell-shaped*, where the corolla is rounded at the base, and gradually enlarged upwards to the summit, so as to resemble a bell in form, as in the Harebell (*fig.* 305).

3. *Infundibuliform* or *funnel-shaped*, where the form of the corolla is that of an inverted cone, like a funnel, as in the Tobacco (*fig.* 306).

4. *Hypocrateriform* or *salver-shaped* (*fig.* 307), where the tube is long and narrow, and the limb placed at right angles to it, as in the Primrose.

5. *Rotate* or *wheel-shaped*, where the tube is short, and the limb at right angles to it, as in the Forget-me-not (*fig.* 308) and Bittersweet (*Solanum Dulcamara*).

6. *Urceolate* or *urn-shaped*, where the corolla is swollen in the middle, and contracted at both the base and apex, as in the Purple Heath (*fig.* 309) and Bilberry (*Vaccinium Myrtillus*).

B. *Irregular Gamopetalous Corollas.*—The following forms are most noteworthy:—

1. *Labiate*, *bilabiate*, or *ringent.*—When the parts of a corolla are so united that the limb is divided into two portions which are

placed superiorly and inferiorly, the upper one overhanging the lower, and each portion so arranged as not to close the orifice of the tube, thus resembling in some degree the lips and open mouth of an animal (*figs.* 310–313), the corolla is termed *labiate*, *bilabiate*, or *ringent*. The upper lip is composed of two petals which are either completely united, as in the White Dead-nettle (*fig.* 301), or more or

FIG. 305.

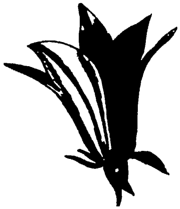


FIG. 307.

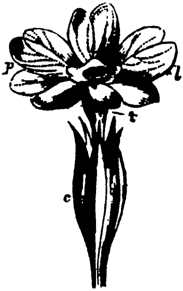


FIG. 306.

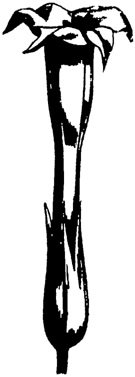


FIG. 308

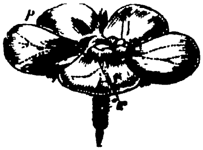


FIG. 309.

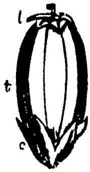


Fig. 305. Flower of the Harebell (*Campanula rotundifolia*), showing a campanulate corolla.——*Fig.* 306. Flower of the Tobacco Plant (*Nicotiana Tabacum*), with infundibuliform corolla——*Fig.* 307. Flower of a species of *Primula*. *c*. Calyx, within which is seen a hypocrateriform corolla, *p*. *t*. Tube of the corolla. *l*. Limb.——*Fig.* 308. Flower of the Forget-me-not (***Myosotis palustris***). *p*. Rotate corolla. *r*. Scales projecting from its throat.——*Fig.* 309. Flower of a species of Heath (*Erica*). *c*. Calyx, within which is an urceolate corolla, *t*, *l*.

less divided, as in the Rosemary (*fig.* 312) and Germander (*Teucrium*) (*fig.* 311); and the lower lip of three petals, which are also either entire, as in the Rosemary (*fig.* 312), or bifid, as in some species of *Lamium*, or trifid, as in *Galeobdolon* (*fig.* 313). When a labiate corolla has its upper lip much arched, as in the White Dead-nettle (*fig.* 310), it is frequently termed *ringent* or *gaping*. The labiate corolla gives the name to the natural order *Labiatæ*, in the plants belonging to which it is of almost universal occurrence. It is found also in certain plants belonging to some other orders.

FIG. 310.

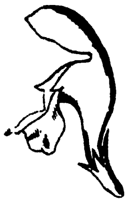


FIG. 311.

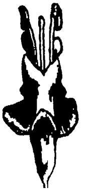


FIG. 312.

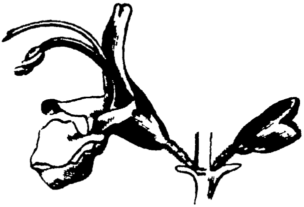


Fig. 310. Ringent or gaping corolla of the Dead-nettle (*Lamium album*), showing the entire upper lip.——*Fig.* 311. Back view of the flower of a species of *Teucrium*, showing the bifid upper lip of the corolla. *Fig.* 312.——Flower of the Rosemary (*Rosmarinus*) with upper lip divided.

2. *Personate or Masked.*—This form of corolla resembles the labiate in being divided into two lips, but it is distinguished by the lower lip being approximated to the upper, so as to close the orifice of the tube or throat. The closing of the throat is caused by a projection of the lower lip called the *palate* (*fig.* 314). Examples occur in the Snapdragon (fig. 314) and the Toadflax (*fig.* 315). In the species of *Calceolaria* the two lips become hollowed out in the form of a slipper; hence such a corolla, which is but a slight modification of the personate, is sometimes termed *calceolate*.

3. *Ligulate or Strap-shaped.*—If what would otherwise be a tubular corolla is partly split open on one side, so as to become flattened like a strap above (*figs.* 316 and 317), it is called *ligulate* or *strap-shaped*. This kind of corolla frequently occurs in the florets of the *Compositæ*, either in the whole of those constituting the capitulum, as in the Dandelion (*Taraxacum*); or only in some of them, as in the outer florets of some species of *Senecio* (*fig.* 239). The apex of a ligulate corolla has frequently five teeth, indicating the number of its component petals (*fig.* 316).

FIG. 313.

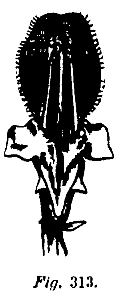


Fig. 313. Front view of the labiate corolla of *Galeobdolon*, with trifid lower lip.

Besides the forms of regular and irregular gamopetalous corollas already described, others also occur, some of which are but slight modifications of these, and arise from irregularities that are produced in certain parts in the progress of their development. In the Foxglove (*fig.* 318) the general appearance of the corolla is somewhat bell-shaped, but it is longer than this form, and slightly irregular, and as it has been supposed to resemble the finger of a

FIG. 314.

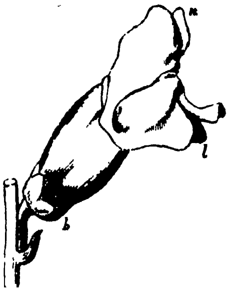


FIG. 315.

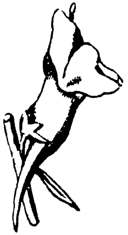


FIG. 316.

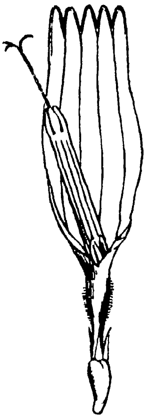


Fig. 314. Personate corolla of the Snapdragon (*Antirrhinum*). *l*. Lower lip. *u*. Upper lip. *b*. Gibbous base.——*Fig.* 315. Personate corolla of the Toadflax (*Linaria*), spurred at its base.——*Fig* 316. Ligulate corolla of a Composite flower, with five teeth at its apex.

FIG. 317.

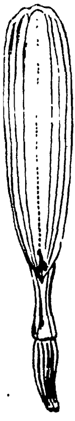


FIG. 318.

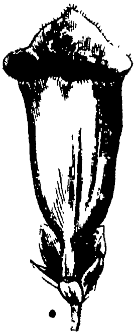


FIG. 319.

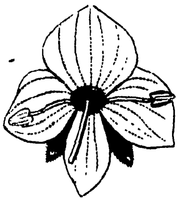


Fig. 317. Ligulate corolla of the Ox-eye (*Chrysanthemum*).——*Fig.* 318. Digitaliform or finger-shaped corolla of the Foxglove (*Digitalis purpurea*).——*Fig.* 319. Irregular rotate corolla of Speedwell (*Veronica*).

glove, it has received the name of *digitaliform* or *finger-shaped*. In the Speedwell (*fig.* 319) the corolla is nearly rotate, but the divisions are of unequal size and shape, hence it may be described as *irregularly rotate*; and in the Red Valerian the corolla is *irregularly salver-shaped* (*fig.* 321).

Appendages of the Corolla.—The corolla, like the calyx, whether polypetalous or gamopetalous, is subject to various irregularities, arising from the expansion or growing outwards of one or more of the petals, or the tube, into processes or appendages of different kinds. In the Snapdragon (*fig.* 314, *b*) and Valerian (*fig.* 320), the lower part of the tube of the corolla becomes dilated on one side, so as to form a little pouch or sac; it is then termed *saccate* or *gibbous*, this term being used in the same sense as previously described when speaking of the calyx. In other cases, one or more of the petals, or the tube, becomes prolonged downwards and forms a *spur*, when the petal or corolla is described as *spurred* or *calcarate*. Examples of spurred petals or corollas may be seen in the Pansy, Columbine (*fig.* 323), Toadflax (*fig.* 315), and Red Valerian (*fig.* 321). Only one spur may be present, as in the Pansy, or each of the petals may be spurred, as in the Columbine (*fig.* 323). The Yellow Toadflax, which usually produces only one spur, in rare instances is found with five. Such a modification of the structure was termed by Linnæus *peloria*, a term which is now frequently applied by botanists in the case of all flowers which thus pass from irregularity to regularity. In the Monkshood (*fig.* 822) each of the two petals

Fig. 320.

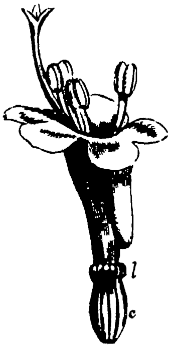


Fig. 321.

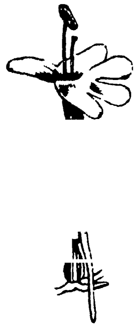


Fig. 320. Flower of a species of Valerian (*Valeriana*). *c*. Calyx, adherent to the ovary. *l*. Limb of the calyx rolled inwards. The corolla has a projection towards its base, and is hence said to be gibbous.—*Fig.* 321. Flower of the Red Valerian (*Centranthus*). The corolla is irregularly salver-shaped and spurred at its base.

which are situated under the helmet-formed sepals already noticed (*fig.* 286) is shaped somewhat like an irregularly curved horn placed on a long channelled stalk.

The corolla is usually composed of but one whorl of petals, and it is then termed *simple*; but in some flowers there are two or more whorls, in which case it is called *multiple*. When the corolla is composed of but one whorl, its parts in a regular arrangement alternate with the sepals, although cases sometimes occur in which they are opposite to them. The causes of these different arrangements have already been explained under the head of the Symmetry of the Flower.

Fig. 322.

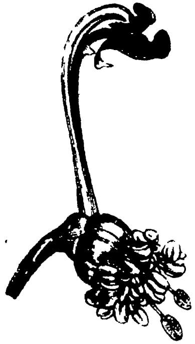


Fig. 323.

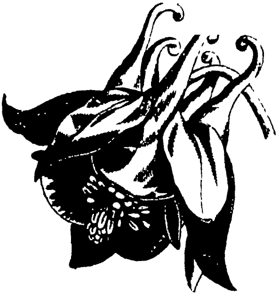


Fig. 322. A portion of the flower of the Monkshood (*Aconitum*), with numerous stamens below, and two stalked somewhat horn shaped petals above.——*Fig.* 323. Flower of the Columbine (*Aquilegia vulgaris*) with each of its petals spurred.

On the inner surface of the petals of many flowers we may frequently observe appendages of different kinds in the form of scales or hair-like processes of various shapes. These are commonly situated at the junction of the claw and limb (*fig.* 327, *a*); or at the base of the petals (*figs.* 324 and 326). Such appendages may be well seen in the Mignonette (*fig.* 325), Buttercup (*fig.* 324), *Lychnis* (*fig.* 327, *a*), and Grass of Parnassus (*fig.* 326). Similar scales may be also frequently noticed in gamopetalous corollas near the throat, as in many members of the *Boraginaceæ*, particularly the Comfrey, Borage, and Forget-me-not (*fig.* 308, *r*); also in the Dodder, and many other plants. Sometimes these scales become more or less united and form a cup-shaped structure, as in the perianth of the Daffodil (*fig.* 328) and other species of *Narcissus*; to this the term *corona* is commonly applied. The beautiful fringes on the corolla of the Passion-flower are of a similar nature.

FIG. 324.

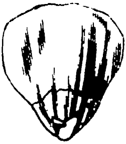


FIG. 325.

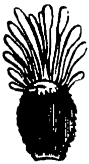


FIG. 326.

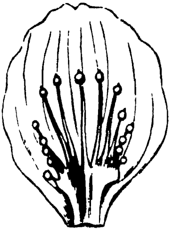


Fig 324. Petal of a Buttercup with a nectariferous scale at its base. *Fig*. 325. One of the petals of Mignonette (*Reseda*) — *Fig* 326. A petal of the Grass of Parnassus (*Parnassia palustris*) bearing a fringed scale at its base.

The origin of all these scales is by no means clearly ascertained; by some botanists they have been supposed to be derived from the petals, by others to be abortive stamens; those

FIG. 327.

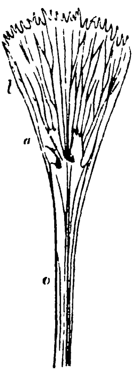


FIG. 328.

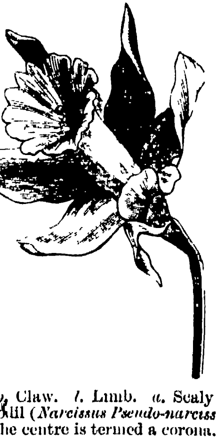


Fig. 327. A petal of a species of *Lychnis*. *o*. Claw. *l*. Limb. *a*. Scaly appendages.——*Fig*. 328. Flower of the Daffodil (*Narcissus Pseudo-narcissus*). The cup- or bell-shaped process towards the centre is termed a corona.

occurring at the junction of the claw and limb are *ligules* developed on the petals. Formerly many of these appendages were described under the name of *nectaries*, although but few of them possess the power of secreting the honey-like matter or nectar from which they derived their names; they were therefore improperly so termed.

DURATION OF THE COROLLA.—The duration of the corolla varies like that of the calyx, but it is almost always more fugitive than the latter. It is *caducous* if it falls as the flower opens, as in the Grape-vine; commonly it is *deciduous*, or falls off soon after the pollination of the flower. In rare instances it is *persistent*, in which case it usually becomes dry and shrivelled, as in Heaths and the species of *Campanula*, when it is said to be *marcescent*.

(3) THE SPOROPHYLLS.

The two whorls of sporophylls have been already termed the Andrœcium and the Gynæcium or Pistil respectively.

Flowers which possess both these whorls have been inaccurately called *hermaphrodite* or *bisexual*, a terminology based upon the now disproved view that the stamens and carpels are male and female organs. As we shall see later, the sexual organs are developed upon the gametophytes to which the spores give origin. A better term for such flowers is *ambisporangiate*. When only one whorl of sporophylls is present, they are *diclinous*, as in *Carex* (*fig.* 329) and *Salix* (*figs.* 214 and 215). Diclinous flowers may be either *staminate* (*figs.* 214 and 329) or *pistillate* (*fig.* 215). In the former case they contain only stamens, in the latter only carpels. In both a perianth is usually present. When a flower possesses neither andrœcium nor gynæcium, as is sometimes the case with the outer florets of the capitula of the *Compositæ*, it is said to be *asporangiate*. When the flowers are diclinous, both staminate and pistillate flowers may be borne upon the same plant, as in the Hazel, Oak, and Arum (*fig.* 201), in which case the plant is called *monœcious*; or upon different plants of the same species, as in the Willows, when the species is termed *diœcious*. In some cases, as in many Palms and in the Pellitory, staminate, pistillate, and ambisporangiate flowers are situated upon the same individual, and then the plant is called *polygamous*.

FIG. 329.

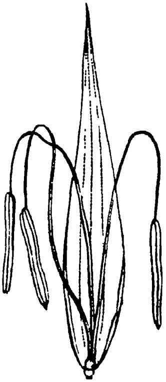


Fig. 329. Staminate flower of a species of *Carex*. The filaments are long and capillary, and the anthers pendulous and innate

c. *The Andrœcium.*

The andrœcium is the whorl or whorls of sporophylls which, in a complete flower, is situated between the corolla or perianth on the outside, and the gynæcium on the inside. The leaves or sporophylls bear the microsporangia, and are termed *stamens* (*fig.* 334). Each is generally composed of a slender portion or stalk, called the *filament*; and of a club-shaped head, *a*, called the *anther*; this consists of a sorus or group of four microsporangia or *pollen-sacs*, which contain the microspores or *pollen-grains*. In certain cases the anthers are not developed, the stamen being then represented by a *staminode*. This commonly presents a flattened appearance, as in the flowers of the species of *Canna*. When, as is rarely the case, the filament is absent, as in the Cuckoo-pint (*fig.* 330), the anther is described as *sessile*.

FIG. 330.

Fig. 330. Stamen of the Cuckoo-pint (*Arum maculatum*), consisting simply of an anther which is sessile upon the thalamus.

Though the microsporangia are usually borne upon sporophylls (stamens), this is not without exception. In some aquatic plants, such as the *Naiadaceæ*, and in some tropical trees, they occur upon certain portions of the axis. When this is the case, the term stamen is still applied to the structure bearing them.

Before discussing the andrœcium as a whole, it will be well to examine the peculiarities of the stamens of which it is composed. Each consists, as we have seen, of a filament and an anther, the latter containing the pollen.

1. THE FILAMENT.—The filament is usually regarded as homologous with the petiole of a leaf. Its importance consists in placing the anther with its sporangia in a position advantageous for the dissemination of the spores or pollen-grains. It consequently varies in form, length, colour, and other particulars; a few of its more important modifications will be now alluded to.

Form.—As its name implies, the filament is usually found in the form of a cylindrical prolongation which generally tapers in an almost imperceptible manner from the base to the apex, as in the Rose. Sometimes the filament, instead of supporting the anther in the erect position as it usually does, becomes curved, and the anther is pendulous as in most Sedges and Grasses (*figs.* 329 and 331). The filament may become enlarged, when it is frequently flattened in various ways. In some cases it is dilated gradually from below upwards like a club, when it is *clavate* or *club-shaped*, as in *Thalictrum*; or it is slightly enlarged at the base, and tapers upwards to a point like an awl, as in the Flowering Rush (*Butomus umbellatus*); in other cases it is flattened at the base, the rest of the filament assuming its ordinary rounded form, as in *Tamarix gallica* (*fig.* 332) and species of *Campanula* (*fig.* 333); the whole of the filament may be flattened, assuming the appearance of a petal, when it is described as *petaloid*, as in the Water-lily (*figs.* 276, *e*, and 346), and in *Canna* and allied plants.

The filament may be *toothed*, as in *Allium* (*fig.* 334), or *forked*, as in *Crambe* (*fig.* 335); or furnished with various appendages, as in the Borage (*fig.* 336, *a*), in which case it is said to be *appendiculate*.

FIG. 331.

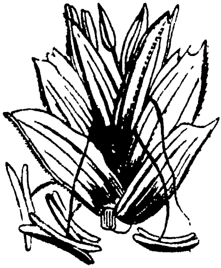


FIG. 332.

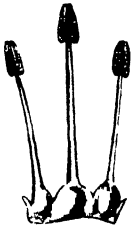


FIG. 333.

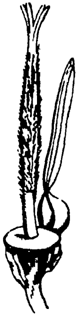


FIG. 334.

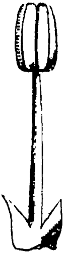


Fig. 331. A locusta of Wheat (*Triticum sativum*), consisting of several flowers, the stamens of which have very long capillary filaments, and versatile pendulous anthers. The anthers are notched or forked at each extremity, and thus resemble somewhat the letter *x* in form.——*Fig.* 332. Three of the stamens of *Tamarix gallica*, with their filaments flattened at the base and united with each other.——*Fig.* 333. Pistil of a species of *Campanula*, with a solitary stamen whose filament is flattened.——*Fig.* 334. Dilated toothed filament of a species of *Allium*.

Colour and Direction.—In *colour* the filaments are generally white, but at other times they assume vivid tints like the corolla or perianth; in the Spiderwort they are blue, in various species of *Ranunculus* and of *Œnothera* yellow, in some Poppies black, in *Fuchsia* red, &c.

In *direction* the filaments, and consequently the stamens, are either *erect*, *incurved*, *recurved*, *pendulous*, &c.: these terms being used in their ordinary acceptation. When the filaments are all turned towards one side of the flower, as in the Horse-chestnut and *Amaryllis*, they are said to be *declinate*. Generally speaking, their direction is nearly the same from one end of the filament to the other, but in some cases the original direction is departed from in a remarkable manner, and the upper part of the filament forms an angle more or less obtuse with the lower, in which case it is termed *geniculate*, as in *Mahernia*. Some confusion may arise from the apparent presence of an articulation in the filament, as in *Euphorbia* (*fig.* 338, *a*). In this case the structure is not to be considered as a true filament, but as consisting in reality of a flower-stalk supporting a single stamen. The flower here, therefore, is reduced to a single stamen, all the parts except the latter being abortive. This is proved by the occasional production in some allied plants of one or more whorls of floral envelopes at the point where the joint is situated. In the Pellitory (*Parietaria*) the filament assumes a spiral direction.

FIG. 335.

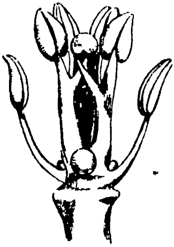


FIG. 336.

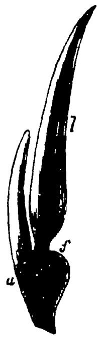


FIG. 337.

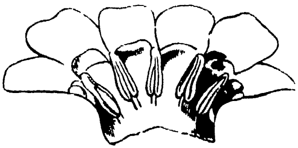


FIG. 338.

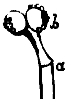


FIG. 339.

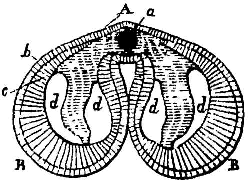


Fig. 335. Gynæcium and andrœcium of *Crambe*. The longer filaments are forked.——*Fig.* 336. A stamen of the Borage (*Borago officinalis*). *f*. Filament. *a*. Curved appendage to the filament. *l*. Anther.——*Fig.* 337. Corolla of *Myosotis* or Forget-me-not, laid open. There are five stamens with very short filaments attached to the corolla and included within its tube ——*Fig.* 338. Staminate flower of *Euphorbia*, consisting of a solitary stamen, *b*, without any floral envelopes surrounding it, hence it is said to be naked or achlamydeous. The anther is two-lobed, and the connective very small. *a*. Articulation, indicating the point of union of the true filament and peduncle, *p*.——*Fig.* 339. Transverse section of a young anther of *Neottia picta*. From Schleiden. A Back of the anther to which the connective is attached. B, B. The two lobes of the anther. *a*. Vascular bundle of the connective. *d*, *d*, *d*, *d*. The four microsporangia or pollen-sacs.

Duration.—The filament usually falls off from the thalamus soon after the flower opens, or is *deciduous*; but in rare cases, as in the species of *Campanula*, it is persistent, and remains attached to the ovary in a withered condition.

2. THE ANTHER.—The anther is essentially a cluster or sorus of microsporangia, the latter being coherent together. The number of the sporangia varies in different families; there are many in some of the Cycads, two in the genus *Pinus*, and usually four in the Angiosperms. The sorus is not covered by any indusium as in the Ferns, though this structure is represented in the young anthers of the *Cupressineæ* by a slight outgrowth from the surface of the sporophyll. The sporangia being coherent together, the anther has usually a somewhat swollen appearance. Their disposition enables us to observe in a transverse section two parallel *lobes*, B, B, separated by a portion, A, *a*, called the *connective*, to which the filament is attached. Each lobe shows the cavities of two microsporangia, *d*, *d*, *d*, *d*, separated by a septum which passes from the connective to the walls of the anther. The microsporangia contain the pollen-grains or microspores. The anthers of Angiosperms in an early stage of development possess four microsporangia, and this is considered the normal state.

When a fully developed anther exhibits a similar structure, as in the Flowering Rush, it is *four-celled* or *quadrilocular* (*figs.* 340, *b*, and 361, *l*); when, as is far more commonly the case, the partitions separating the two sporangia of each anther-lobe become absorbed, it is *two-celled* or *bilocular* (*fig.* 360). In rare cases the anther is *unilocular*, or *one-celled*, as in the Mallow (*fig.* 359), Milkwort (*fig.* 341), and Lady's Mantle (*fig.* 342); this arises either from the abortion of one lobe of the anther and the absorption of the septum between the two sporangia of the lobe that is left, or from the destruction of the partition wall of the two lobes as well as of the septa between the sporangia of each lobe. In many species of *Salvia*, the connective becomes elongated into a kind of stalk, each end of which bears an anther-lobe (*fig.* 343). When this occurs one lobe only, *lf*, contains pollen; the other, *ls*, is sterile. That surface of the anther to which the connective is attached is called the *back* (*fig.* 339, A), and the opposite surface, B, B, is the *face*. The latter always presents a more or less grooved appearance (*figs.* 339 and 344, *c*), indicating the line of junction of the two lobes. Each lobe also commonly presents a more or less evident furrow (*fig.* 344, *b*), indicating the point at which the mature anther will open to discharge the pollen; this furrow is termed the *suture*. By these furrows the face of the anther may be generally distinguished from the back, which is commonly smooth (*fig.* 339, A), and has moreover the filament attached to it. The face is generally turned towards the gynæcium or centre of the flower, as in the Water-lily (*fig.* 346), Vine (*fig.* 344), and Tulip (*fig.* 347), in which case the anther is called *introrse*; but in some instances, as in the Iris and Meadow Saffron (*fig.* 345), the face is directed towards the petals or circumference of the flower, when the anther is said to be *extrorse*.

FIG. 340.

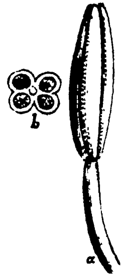


FIG. 341.

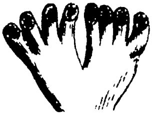


FIG. 342.

FIG. 343.

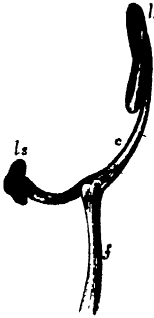


FIG. 344.

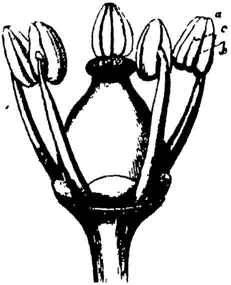


FIG. 345.

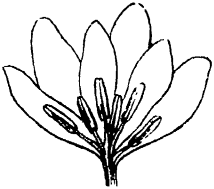


Fig. 340. Four-celled anther of the Flowering Rush (*Butomus umbellatus*). *a*. Filament bearing an entire anther. *b*. Section of the anther with its four cells.——*Fig.* 341. Andrœcium of Milkwort (*Polygala*), with eight one-celled anthers dehiscing at their apex.——*Fig.* 342. One of the stamens of the Lady's Mantle (*Alchemilla*). The anther is one-celled, and dehisces transversely.——*Fig.* 343. Stamen of the Sage (*Salvia*). *f* Filament. *c*. Elongated connective, separating the two lobes of the anther, one of which, *lf*, produces pollen, while the other, *ls*, is sterile.——*Fig.* 344. The andrœcium and gynœcium of the Vine (*Vitis vinifera*). *a*. Anther. *c*. Furrow in its face which is turned towards the pistil or gynœcium. *b*. Suture or line of dehiscence. The anther is introrse.——*Fig.* 345. The perianth cut open, showing the stamens, of the Meadow Saffron (*Colchicum autumnale*), with extrorse anthers.

Attachment of the Filament to the Anther.—The mode in which the anther is attached to the filament varies in different plants, but is always constant in the same species, and frequently throughout entire Natural Orders, and hence the characters afforded by such differences are important in systematic botany. There are three modes of attachment, which are distinguished by special names. 1st, the anther is said to be *adnate* or *dorsifixed* when its back is attached throughout its whole length to the filament, or to its continuation the connective, as in the Magnolia (*fig.* 350) and Water-lily (*fig.* 346); 2nd, it is *innate* or *basifixed* when the filament is only attached to its base, and firmly adherent, as in the species of *Carex* (*fig.* 329); 3rd, it is *versatile*, when the filament is only attached by a point to about the middle of the back of the connective, so that the anther swings upon it, as in Grasses generally (*fig.* 331), and in the Lily, Evening Primrose, and Meadow Saffron.

Connective.—The relations of the anther to the filament, as well as of its lobes to each other, are much influenced by the appearance and size of the connective. In all adnate anthers the connective is large, and the lobes generally more or less parallel to each other throughout their whole length (*fig.* 350). In other cases the connective is very small, or altogether wanting, as in species of *Euphorbia* (*fig.* 348), so that the lobes of the anther are then immediately in contact at their base. In the Lime the connective completely separates the two lobes of the anther (*fig.* 349). In the Sage and other species of *Salvia* the connective forms a long stalk-like body placed horizontally on the top of the filament; one end of it bears an anther-lobe, *lf*, containing pollen, the other merely a petaloid plate or abortive anther-lobe, *ls* (*fig.* 343); it is then said to be *distractile*. Sometimes the connective is prolonged beyond the lobes of the anther; either as a little rounded or tapering expansion, as in the Magnolia (*fig.* 350), or as a long feathery process, as in the

FIG. 346.

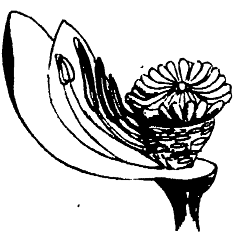


FIG. 347.

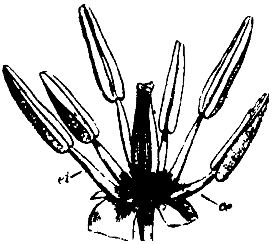
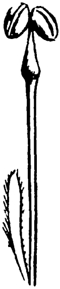


Fig. 346. A portion of the flower of the White Water-lily (*Nymphæa alba*), showing the gynæcium invested by a large fleshy disc which is prolonged from the thalamus. Below the pistil are some stamens which have petaloid filaments and adnate introrse anthers; two petals are shown, the others having been removed.—*Fig.* 347. Gynæcium and andrœcium of the Tulip. The stamens *ei* and *ce* have introrse anthers, which dehisce longitudinally.

Oleander (*fig.* 352), or in various other ways. At other times, again, it is prolonged downwards and backwards as a kind of spur, as in the Pansy (*fig.* 351). Anthers with such appendages are termed *appendiculate*.

FIG. 348.



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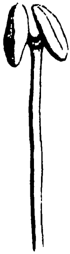


FIG. 350.

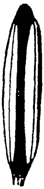


FIG. 351.

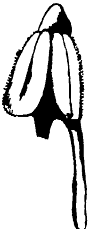


FIG. 352.

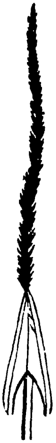
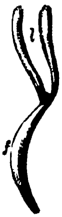


Fig. 348. A male naked flower of a species of *Euphorbia*, showing the two lobes of the anther, and the almost total absence of the connective.——*Fig.* 349. A stamen of the Lime (*Tilia*), showing the large connective separating the lobes of the anther.——*Fig.* 350. A view of the inner face of a stamen of *Magnolia glauca*, showing the adnate anther and prolonged connective.——*Fig.* 351. Two stamens of the Pansy (*Viola tricolor*). The connective of one of them is prolonged downwards in the form of a spur.——*Fig.* 352. Sagittate anther-lobes of the Oleander (*Nerium oleander*), and the prolonged feathery connective.

The lobes of the anther also, like the connective, frequently present appendages of various kinds. In *Erica cinerea* they have a flattened leafy body at their base (*fig.* 356, *a*); at other times the surface of the anther presents projections in the form of pointed bodies (*fig.* 357, *a*), as in *Vaccinium uliginosum*, or warts, &c. Such

FIG. 353.



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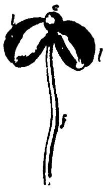


FIG. 355.

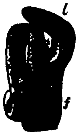
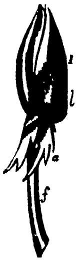


Fig. 353. A stamen of a species of *Acalypha* in a young state. *f.* Filament. *l.* Linear anther-lobes.——*Fig.* 354. A stamen of *Mercurialis annua*. *f.* Filament. *c.* Connective. *l, l.* Rounded anther-lobes dehiscing longitudinally.——*Fig.* 355. The linear and sinuous anther-lobes, *l*, attached to the filament, *f*, of the common Bryony (*Bryonia dioica*).

anthers, like those which present appendages from the connective, are termed *appendiculate*.

Dehiscence of the Anther.—When the anthers are perfectly ripe the pollen-sacs or miscrosporangia open and discharge their contained pollen (*fig.* 359); this act is called the *dehiscence* of the anther. Dehiscence commonly takes place in the line of the sutures (*fig.* 344, *b*), and at the period when the flower is fully expanded; at other times, however, the anthers burst before the flower opens. All the anthers may open at the same period, or in succession; and in the latter case the dehiscence may either commence with the outer stamens, as is usually the case, or rarely with the inner.

FIG. 356.



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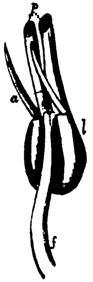

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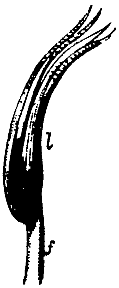


Fig. 356. Appendiculate anther attached to filament, *f*, of the Fine-leaved Heath (*Erica cinerea*). *a*. Appendage. *l*. Lobes. *s*. Lateral short slit where dehiscence takes place.——*Fig.* 357. Bifurcate anther of *Vaccinium uliginosum* attached to filament, *f*. *l*. Anther-lobes. *a*. Appendages. *p*. Points of the anther-lobes where dehiscence takes place.——*Fig.* 358. Quadrifurcate anther of *Gaultheria procumbens*, attached to filament, *f*. *l*. Anther-lobes.

The dehiscence of the anther may take place in four different ways, which are respectively called: 1. *Longitudinal*; 2. *Transverse*; 3. *Porous*; 4. *Valvular*.

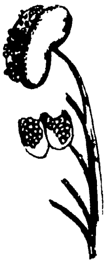
1. *Longitudinal or Sutural.*—This, the usual mode of dehiscence, consists in the opening of each anther-lobe from the base to the apex in a longitudinal direction along the line of suture, as in the Vine (*fig.* 344, *c*) and Tulip (*fig.* 347).

2. *Transverse.*—This kind of dehiscence occurs in unilocular anthers, as in those of *Alchemilla* (*fig.* 342), *Lemna*, and *Lavandula*. It sometimes happens that by the enlargement of the connective the loculus of a one-celled anther is placed horizontally instead of vertically, in which case the dehiscence when it takes place in the

line of the suture is apparently transverse, although it is really longitudinal. An example of this kind of dehiscence is afforded by the Mallow and other plants belonging to the Natural Order *Malvaceæ* (*fig.* 359).

3. *Porous or Apical.*—This is a mere modification of longitudinal dehiscence. It is formed by the splitting down of the anther-lobes being arrested at an early period so as only to produce pores or short slits. In such anthers there is commonly no trace of the sutures to be seen externally. The pores or slits may be situated either at the apex, as in the species of *Solanum* (*fig.* 363) and Milkwort (*fig.* 341); or laterally, as in the Heaths (*fig.* 356, *r*). There may be either two pores, as is usually the case (*fig.* 360, *p*), or four, as in *Poranthera* (*fig.* 361, *p*), or many, as in the Mistletoe, or only one, as in *Tetratheca juncea* (*fig.* 362).

FIG. 359.



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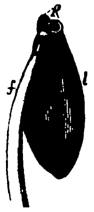

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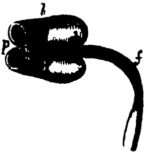


FIG. 362.

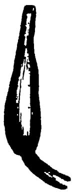


FIG. 363.

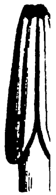


Fig. 359. Stamen of the Mallow (*Malva*), the anther of which has an apparently transverse dehiscence.——*Fig.* 360. Two-celled anther of *Pyrola rotundifolia*, suspended from the filament, *f*. *l*. Loculi, each opening by a pore, *p*.——*Fig.* 361. Quadrilocular anther of *Poranthera*, attached to filament, *f*. *l*. Loculi, each opening by a pore, *p*.——*Fig.* 362. Anther of *Tetratheca juncea*, opening by a single pore at the apex. These figures are from Jussieu.——*Fig.* 363. Anther-lobes of a species of *Solanum*, each opening by a pore at the apex.

4. *Valvular.*—This term is applied when the whole or portions of the face of the anther open like trap-doors, which are attached at the top and turn back as if on a hinge. In the Barberry (*fig.* 364) there are two such valves; in plants belonging to the Laurel family (*fig.* 365) there are two or four, according to the number of the loculi of the anther.

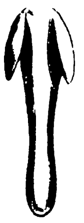
We may now consider the andrœcium as a whole from the point of view of the relations of the stamens to each other, and to the other whorls of the flower, noting the following points:—1. Number; 2. Insertion or Position; 3. Union or Cohesion; 4. Relative Length.

1. *Number.*—The number of the stamens is subject to considerable variation; normally they are equal in number to the sepals and petals, the flower being *isostemonous*; sometimes they are twice as numerous (*diplostemonous*). The number may, however, bear no exact relation to the number of the perianth leaves, the irregularity being due to various causes which will be discussed later.

When the stamens are free their number is expressed by the Greek numerals prefixed to the termination *-androus*; a flower having one stamen is *monandrous*, one with two, *diandrous*, and so on.

2. *Insertion or Position or Adhesion.*—When the stamens are free from the calyx and pistil, and arise from the thalamus below the latter organ, as in the Barberry (*fig.* 398) and Crowfoot (*fig.* 366), they are said to be *hypogynous*; this is their normal position. When the stamens are attached to the corolla, as in the Primrose (*fig.* 367), they are *epipetalous*. When they apparently adhere to the receptacular tube, so that their position becomes somewhat lateral to the pistil instead of below it, as in the Cherry (*fig.* 368), they as well as the corolla are said to be *perigynous*. When the thalamus or the calyx is adherent to the ovary, so that the calyx appears to arise from its apex, the intermediate stamens and petals or corolla are also necessarily placed on the summit, and are said to be *epigynous*, as in the species of *Campanula* (*fig.* 369) and Ivy. It sometimes happens that the stamens not only adhere to the ovary or lower part of

FIG. 364.



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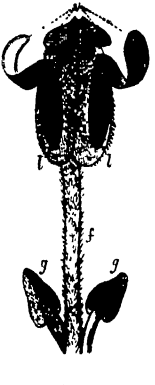


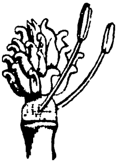
Fig. 364 Anther of Barberry (*Berberis vulgaris*), opening by two valves. *Fig.* 365. Stamen of a species of *Laurus*. *f.* Filament, with two glands, *g*, *g*, at its base. *l*, *l*. Loculi, of which there are four. *v*. Valves.

the pistil, as in the epigynous form of insertion, but the upper part of the stamen or stamens and that of the pistil become completely united also, and thus form a column in the centre of the flower, as in *Orchis* (*fig.* 370) and *Aristolochia* (*fig.* 371); this column is then termed the *gynostemium*, and the flowers are said to be *gynandrous*.

3. *Union or Cohesion.*—When the stamens are perfectly free and separate from each other, as in the Vine (*fig.* 344), they are said to be *free* or *polyandrous*; they may, however, be united by either their filaments or their anthers.

When the anthers are united, the stamens are termed *syngenesious* or *synantherous* (*fig.* 372). This union occurs in all the *Compositæ*, the Lobelia, and in some other plants. When the anthers are thus united the filaments are commonly, though not always, distinct. When cohesion occurs in the staminal whorl, however, it is more usual to see the filaments united, and the anthers free. This union by the filaments may gather them into one or more bundles, the number being expressed by a Greek numeral prefixed to the termination *-adelphous*. When all the filaments unite together and form one bundle, as in the Mallow (*fig.* 373) and Wood Sorrel (*fig.* 374), the stamens are said to be *monadelphous*. When such a union takes place in a complete flower, the coherent filaments necessarily form a tube or ring round the pistil placed in their centre, as in the Wood Sorrel (*fig.* 374); when the pistil is absent, and the

FIG. 366.



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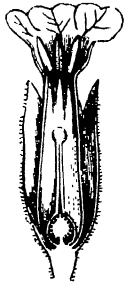


FIG. 368.

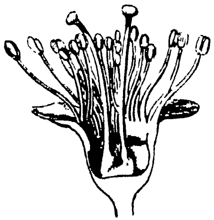
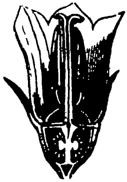
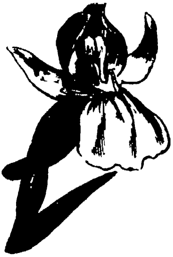


Fig. 366. Apocarpous pistil of the Crowfoot (*Ranunculus*), with two stamens arising from the thalamus below it, or hypogynous.—*Fig.* 367. Vertical section of a flower of the Primrose (*Primula*), showing epipetalous stamens. The pistil in the centre has an ovary with a free central placenta, one style, and a capitate stigma.—*Fig.* 368. Vertical section of the flower of the Cherry, showing the perigynous stamens surrounding the pistil.

flower therefore incomplete, the united filaments form a more or less central column, as in *Jatropha Curcas* (*fig.* 375, *a*).

FIG. 369. FIG. 370. FIG. 371.





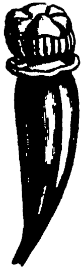
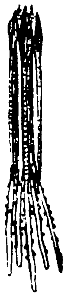
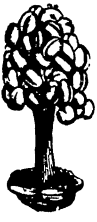


Fig. 369. Vertical section of the flower of a species of *Campanula*, with epigynous stamens.——*Fig.* 370. Flower of *Orchis mascula*. The column in the centre is formed by the union of the stamens and style.——*Fig.* 371. The pistil and stamens of Birthwort (*Aristolochia*). The ovary is seen below, and the stamens above united into a column with the style.

When the filaments unite so as to form two bundles, the stamens are termed *diadelphous*, as in the Pea (*fig.* 376),

FIG. 372. FIG. 373. FIG. 374.





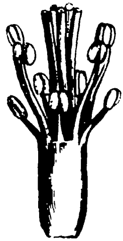


FIG. 375.

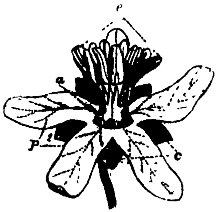


Fig. 372. Syngenesious anthers of a species of Thistle (*Carduus*).——*Fig.* 373. Monadelphous stamens of a species of Mallow (*Malva*).——*Fig.* 374. Monadelphous stamens of Wood Sorrel (*Oxalis*), forming a tube round the pistil. *Fig.* 375. Male flower of *Jatropha Curcas*. *c*. Calyx. *p*. Corolla. *e*. Stamens united by their filaments into a tube, *a*, which occupies the centre of the flower, as there is no pistil.

Milkwort (*fig.* 341), and Fumitory; the filaments in each bundle may be equal in number, as in the Milkwort (*fig.* 341) and Fumitory; or unequal, as in the Sweet Pea (*fig.* 376), where there are ten stamens, the filaments of nine of them being united to form one bundle, while the other filament remains free. The bundle in this case is made up of five stamens belonging to one whorl and four belonging to the other, the andrœcium in the Pea family being composed of two whorls with five stamens in each. When the stamens are united by their filaments into three bundles, they are *triadelphous*, as in most species of St. John's Wort (*fig.* 378); and when in more than three, *polyadelphous*, as in the Orange (*fig.* 377).

The union of the filaments in the above cases may either be more or less complete, extending over their whole length, and thus forming a tubular column round the style or styles, as in the Mallow (*fig.* 373) and Wood Sorrel (*fig.* 374); or the union may only take place at the base, as in *Tamarix gallica* (*fig.* 332). The bundle or bundles, again, may be either unbranched, as in the Wood Sorrel (*fig.* 374); or branched, as in the Milkwort (*fig.* 341) and Castor-oil Plant (*fig.* 379). When the united filaments form a tube or column, the term *androphore* has been applied to such a structure, as in the Mallow (*fig.* 373) and Wood Sorrel *fig.* 374).

FIG. 376.

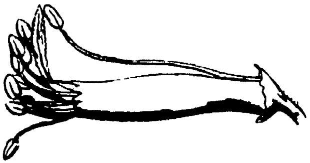


FIG. 377.

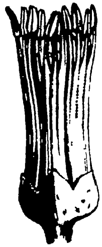


Fig. 376. Diadelphous stamens of the Sweet Pea (*Lathyrus odoratus*), surrounding the simple pistil. There are ten stamens, nine of which are united and one free.——*Fig.* 377. Flower of the Orange divested of its corolla, to show the polyadelphous stamens.

4. *Relative Length.*—There are two separate subjects to be treated of here, namely, the relative length of the stamens with respect to the corolla; and their length with respect to each other. When the stamens are shorter than the tube of the corolla, so as to be enclosed within it, as in the Forget-me-not (*fig.* 337), they are said to be *included*; and when they are longer than the tube of the corolla, so as to extend beyond it, as in the Valerians (*figs.* 321 and 380), they are *exserted* or *protruding.*

The relative length of the stamens with respect to each other presents several peculiarities. Sometimes all the stamens of the flower are nearly of the same length, while at other times they are very unequal. This inequality may be altogether irregular, following no definite rule, or take place in a definite and regular manner; when the flowers are polystemonous, the stamens nearest the centre may be longer than those at the circumference, as in *Luhea paniculata* (*fig.* 381); or the reverse may be the case, as in many of the *Rosaceæ*. In the case of diplostemonous flowers, such as the Willow Herb (*Epilobium*), the stamens alternating with the petals are almost always longer than those opposite to them. When the stamens are of two different lengths in different flowers of the same species, as in the Primrose, the latter are said to be *dimorphic*. This condition will be afterwards alluded to in speaking of fertilisation.

FIG. 378.

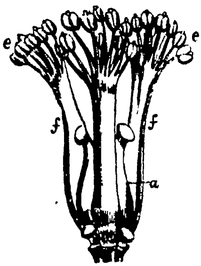


FIG. 379.

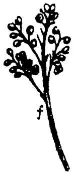


FIG. 380.

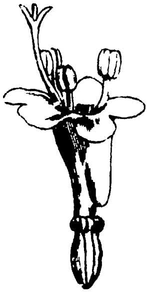


Fig. 378. The pistil, *a*, of *Hypericum ægyptiacum*, surrounded by the stamens, *e*, *e*, which are united by their filaments, *f*, *f*, into three bundles.—*Fig.* 379. One of the branched bundles of stamens of the Castor-oil Plant (*Ricinus communis*). *f*. United filaments.—*Fig.* 380. Flower of a species of Valerian (*Valeriana*), showing the stamens prolonged beyond the tube of the corolla, exserted. The corolla is gibbous at the base.

When there is a definite relation existing between the long and short stamens with respect to number, certain names are applied to indicate such forms of regularity. In the Wallflower (*fig.* 382), and other members of the *Cruciferæ*, there are six stamens to the flower, of which four are long and arranged in pairs opposite to each other; alternating with these pairs are two solitary shorter ones; to such an arrangement we apply the term *tetradynamous*. When there are but four stamens, of which two are long and two short, as in the members of the *Labiatæ* (*figs.* 311 and 313), and in the Foxglove (*fig.* 383), and most other plants of the Natural Order *Scrophulariaceæ*, they are said to be *didynamous*.

3. THE POLLEN.—The pollen consists of microscopic cells which correspond to the *microspores* of the higher Cryptogams. They possess two coats, known as the *extine* and the *intine*. In rare cases the outer coat appears to consist of two, or even three, layers; while in *Zostera*, *Zannichellia*, and some other submersed aquatic plants, there is but one membrane, which is of a similar nature to the intine.

The *intine* is the innermost layer, and appears to be of the same nature and appearance in all pollen-grains. It is usually smooth, very delicate, and transparent, and is composed of unchanged cellulose.

The *extine* is a hard thick resisting layer, and is liable to great variation; it is sometimes smooth, at other times marked with little granular processes, or spiny protuberances (*fig.* 384), or reticulations (*fig.* 388). The nature of these markings is always the same for the pollen of any particular species or variety of plant, but varies much in that of different plants. The extine is often covered by a viscid or oily secretion. The colour of pollen-grains is found in the extine. In by far the majority of cases they are yellow, but various other colours are also occasionally found; they are red in species of *Verbascum*, blue in some species of *Epilobium*, black in the Tulip, rarely green, and occasionally of a whitish tint.

FIG. 381.

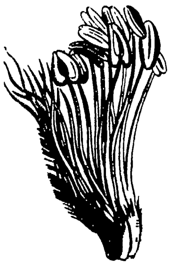


FIG. 382.

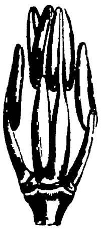


FIG. 383.

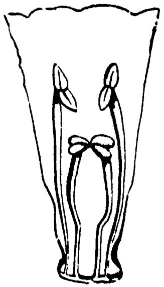


Fig. 381. One of the bundles of stamens of *Luhea paniculata*; the inner stamens on the right are longer than the others, and are provided with anthers; the shorter stamens are generally sterile.——*Fig.* 382. Tetradynamous stamens of the Wallflower (*Cheiranthus Cheiri*).——*Fig.* 383. Didynamous stamens of the Foxglove (*Digitalis purpurea*).

Besides the various markings just described as existing on the extine, we find also either *pores* (*fig.* 387) or *slits* (*figs.* 385, *f*, and 386, *f*), or both pores and slits, which vary in number and arrangement in different plants. In the greater number of Monocotyledons there is but one slit; while three is a common number in Dicotyledons. Sometimes there are six, rarely four, still more rarely two, and in some cases we find twelve or more slits. These slits are generally straight (*fig.* 385, *f*), but in *Mimulus moschatus* they are curved. Other still more complex arrangements occasionally occur.

FIG. 384.

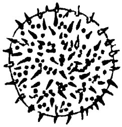


FIG. 385.

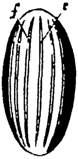


FIG. 386.

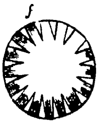


FIG. 387

Fig. 384. Pollen of Hollyhock (*Althæa rosea*).——*Fig.* 385. Elliptical pollen of Milkwort (*Polygala*). *e*. Extine. *f*. Slits.——*Fig.* 386. The same pollen viewed from above.——*Fig.* 387. Pollen-cell of *Dactylis glomerata*. After Jussieu.

The pores, like the slits, vary in number. We commonly find one in Monocotyledons, as in the Grasses; and three in Dicotyledons. Sometimes, again, the pores are very numerous, in which case they are either irregularly distributed, or arranged in a more or less regular manner. The pores may be either simple, or provided with little lid-like processes, as in the Passion-flower (*fig.* 388, *o*, *o*, *o*) and Gourd (*fig.* 389). These processes (*fig.* 389, *o*, *o*) are pushed off by corresponding projections of the intine, *t*, *t*, when the pollen germinates; hence such pollen-grains have been termed *operculate*. In the pollen-grains of some of the Firs, the extine is expanded on two sides to form two curious bladder-like protuberances (*fig.* 391).

FIG. 388. FIG. 389. FIG. 390.

Fig. 388. Pollen of the Passion-flower (*Passiflora*), before bursting. *o*, *o*, *o*. Lid-like processes.——*Fig.* 389. Pollen of the Gourd, at the period of bursting. *o*, *o*. Lid-like processes of the extine protruded by the projections, *t*, *t*, of the intine. From Jussieu.——*Fig.* 390. Trigonal pollen of the Evening Primrose (*Œnothera biennis*).

The pollen-grains are usually free in the loculi of the anther.

Sometimes, though rarely, they adhere to a greater or less extent to each other. We have groups of four in *Periploca græca*, eight in *Inga anomala*; or some higher multiple of four, as in many species of *Acacia*. In the *Onagraceæ*, the pollen-grains are loosely connected by long viscid filaments or threads; while in the *Orchidaceæ* those of each pollen-sac cohere together and form pollen-masses, to which the name of *pollinia* has been given (*fig.* 392, *p*). In the *Asclepiadaceæ* somewhat similar masses occur (*fig.* 393, *p* and *b*); but in the latter the whole surface of each pollen-mass is invested by a special covering. By a careful examination of these pollinia we find that they are formed of definite masses agglutinated together, and, when separated, each of these masses is found to consist of four pollen-grains. In the pollinia of the *Orchidaceæ* we also find other peculiarities; each is prolonged downwards in the form of a stalk called the *caudicle* (*fig.* 392, *c*), which adheres commonly at the period of dehiscence to one or two little glandular masses called *retinacula* (*figs.* 394, *a*, and 392, *r*, *r*). These are

FIG. 391.

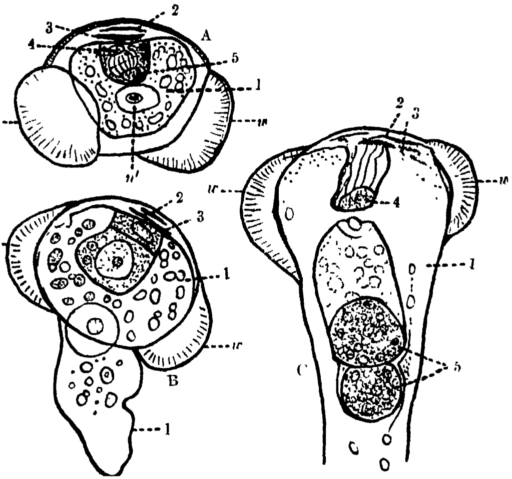


Fig. 391. A. Pollen-grain of *Picea excelsa*, showing commencement of germination. *w*, *w*. The wings. 1. The large vegetative cell; its protoplasm is contracted; *n'*, its nucleus; 2, 3, the two collapsed cells; 4 and 5, the stalk cell and generative cell not yet completely divided from one another. B. A little older grain, showing germination a little further advanced and the pollen-tube beginning to appear as an outgrowth of the large cell, 1. Lettering as before. C. More advanced stage, showing only upper part of the pollen-tube. The generative cell, 5, has divided into two, each with a very large nucleus. × 240. After Strasburger.

placed on the upper surface of a little projection called the *rostellum*, situated at the base of the anther.

Pollen-grains are found of various shapes. The most common forms appear to be the spherical (*fig.* 384) and ovoid (*fig.* 385); in other cases they are polyhedral, as in Chicory (*Cichorium Intybus*) and *Sonchus palustris*, or triangular with the angles rounded and enlarged (trigonal), as in the Evening Primrose (*Œnothera biennis*) and other plants of the order *Onagraceæ* (*fig.* 390), or cubical as in *Basella alba*, or cylindrical as in *Tradescantia virginica*, while in *Zostera* they are thread-like or of the form of a lengthened tube or a cylinder; other shapes also occur. The form of the pollen is materially influenced by differences of dryness or dampness. The pollen-grains of the Purple Loosestrife (*Lythrum Salicaria*) and some species of Passion-flower are ovoid when dry, but when placed in water they swell and become nearly globular. Again, when spherical pollen-grains are exposed to the air for some time they frequently assume a more or less ovoid form.

FIG. 392.

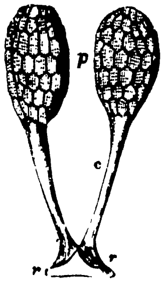


FIG. 393.

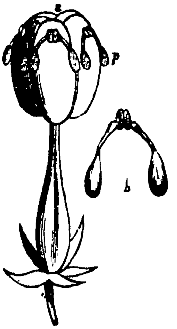


FIG. 394.

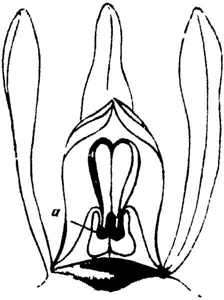


Fig. 392. Pollinia, *p*, of a species of Orchis with their caudicles, *c*, adhering to the retinacula, *r*, *r*.——*Fig.* 393. Pistil of a species of *Asclepias*, with the pollinia, *p*, adhering to the stigma, *s*. *b*. Pollen-masses separated. *Fig.* 394. Upper part of the flower of an Orchis, showing the pollinia adhering to the column by the retinacula, *a*.

In size, pollen-grains vary from about $\frac{1}{200}$ to $\frac{1}{1000}$ of an inch in diameter; their size, however, like their form, is liable to vary as they are examined in a dry state or in water.

d. *The Gynæcium or Pistil.*

The gynæcium, or pistil, consisting of a variable number of constituent sporophylls, or *carpels*, occupies the centre of the flower, the andrœcium and floral envelopes being arranged around it when they are present; the floral envelopes alone surround it in the ordinary pistillate flower; while it stands alone when the flower is pistillate and naked. Its sporophylls are much more frequently united together than those of the andrœcium, so that a compound ovary is of very common occurrence (*figs*. 367, 397).

FIG. 395.

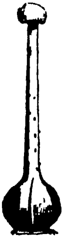


FIG. 396.

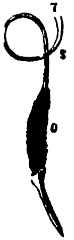


FIG. 397.

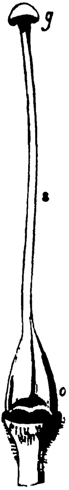


FIG. 398.

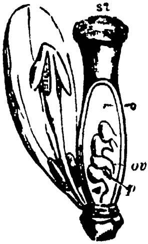


FIG. 399.

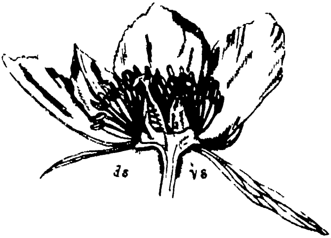


Fig. 395. Pistil of Primrose (*Primula vulgaris*), composed of several united carpels, and hence termed compound and syncarpous. There is but one style, which is surmounted by a capitate stigma.—*Fig*. 396. Simple pistil of Broom. *o*. Ovary. *s*. Style. *t*. Stigma.——*Fig*. 397. Compound syncarpous pistil of Tobacco (*Nicotiana Tabacum*). *t*. Thalamus. *o*. Ovary. *s*. Style. *g*. Capitate stigma.——*Fig*. 398. Vertical section of the ovary of the Barberry (*Berberis vulgaris*), on the outside of which are seen a stamen, dehiscing by two valves, and a petal. *o*. Ovary. *ov*. Ovules attached to a projection called the placenta, *p*. *st*. Sessile stigma.——*Fig*. 399. Vertical section of the flower of the Pæony (*Pæonia*). *ds*. Dorsal suture of the ovary. *vs*. Ventral suture.

When there is but one carpel, as in the Pea (*fig*. 406), Broom (*fig*. 396), and other members of the *Leguminosæ*, the pistil is said to be *simple*; when there is more than one, it is described as *compound*, whether they are distinct from each other, as in the Crowfoot (*fig*. 366), or combined into one body, as in the Tobacco (*fig*. 397) and Primrose (*fig*. 367).

Each carpel consists typically of three parts: 1st, of a hollow inferior portion called the *ovary* (*fig.* 398, *o*), containing one or more little somewhat roundish or oval bodies called *ovules* (*ov*) or *megasporangia*, which are attached to a projection on the walls termed the *placenta*, *p*; 2nd, of an apical sticky portion called the *stigma*; 3rd, of an elongated stalk rising from the ovary, and bearing the stigma. This is called the *style*. In some cases it is not developed, and the stigma is said to be sessile. The terms ovary, style, and stigma are applied in precisely the same sense, when speaking of a compound pistil in which the parts are completely united (*figs.* 367, 395, 397), as in the case of a simple carpel. The monocarpellary ovary has two sutures, one which corresponds to the union of the margins of the lamina of the carpellary leaf, and is turned towards the axis of the plant; and another which corresponds to the midrib of the lamina, and is directed towards the floral envelopes or the circumference of the flower; the former is called the *ventral* (*fig.* 399, *vs*), the latter the *dorsal* (*ds*) *suture*.

FIG. 400.

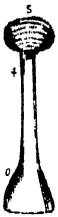


FIG. 401.

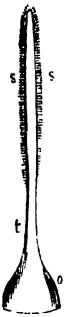


FIG. 402.

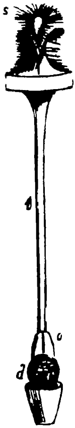


FIG. 403.

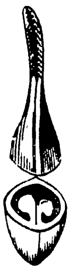


FIG. 404.

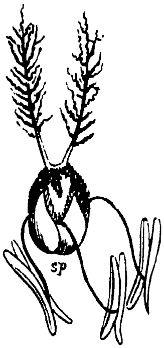


Fig. 400. A portion of the pistil of *Daphne Laureola*. *o*. Summit of the ovary. *t*. Style terminated by a stigma, *s*.—*Fig.* 401. A portion of the pistil of *Plantago saxatilis*. *o*. Summit of the ovary. *t*. Style. *s*, *s*. Bilateral stigma. The above figures are from Jussieu.—*Fig.* 402. Pistil of the Periwinkle (*Vinca*). *o*. Ovary. *t*. Style. *s*. Hairy stigma. *d*. Disc. *Fig.* 403. Ventral view of the pistil of *Isopyrum biternatum*, showing the double stigma. *Fig.* 404. Pistil of Wheat (*Triticum sativum*) surrounded by three stamens and three squamulæ, *sp*. Two feathery styles or stigmas arise from the top of the ovary.

When the gynæcium is formed of but one carpel, as in the Broom (*fig.* 396) and Pea (*fig.* 406), it is, as we have already seen, called *simple*, and the terms *gynæcium*, or *pistil*, and *carpel* are then synonymous; when there is more than one carpel, the pistil or gynæcium is termed *compound* (*figs.* 395 and 410). In a compound pistil, again, the carpels may be either separate from each other, as in the Stonecrop (*fig.* 284) and Pheasant's-eye (*fig.* 410); or united into one body, as in the Primrose (*fig.* 395), Carnation (*fig.* 405), and Tobacco (*fig.* 397): in the former case the pistil is said to be *apocarpous*, in the latter *syncarpous*. The number of carpels of which the pistil is composed is expressed by a Greek numeral prefixed to the termination *-gynous*; and the flower receives corresponding names accordingly. A flower with one carpel is *monogynous*; with two, *digynous*, and so on.

FIG. 405.

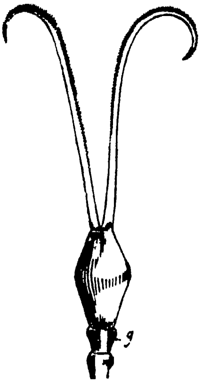


FIG. 406.

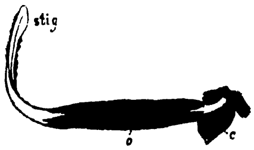


Fig. 405. Pistil of *Dianthus Caryophyllus* on a stalk, *g*, called the gynophore, below which is the peduncle. On the top of the ovary are two styles, the face of each of which is traversed by a continuous stigmatic surface.—*Fig.* 406. Pistil of *Lathyrus odoratus*. *o*. Ovary. *c*. Persistent calyx. On the top of the ovary is the style and stigma, *stig*.

1. *Apocarpous Pistil.*—An apocarpous pistil may consist of one or more carpels, and they may be arranged in various ways. When there are but two, they are always placed opposite to each other; when there are more than two, and the number coincides with that of the sepals or petals, they are usually opposite to the latter; it is rare, however, to find the carpels corresponding in number to the sepals or petals; they are generally fewer or more numerous. The carpels may either be arranged in one whorl, as in the Stonecrop (*fig.* 284), or in several whorls alternating with each other, or they may form a more or less spiral arrangement upon the thalamus.

When an apocarpous pistil is thus found with several rows of carpels, the thalamus, instead of having a nearly flattened top, as is usually the case when the number of carpels is small, frequently assumes other forms; in the *Magnolia* and Tulip-tree, it becomes cylindrical (*fig.* 407); in the Raspberry (*fig.* 409, *l*) and *Ranunculus* (*fig.* 366) conical; in the Strawberry (*fig.* 408) hemispherical; while in the Rose (*fig.* 285, *r, r*) it is hollowed out like a cup, or urn, and has the carpels arranged upon its inner surface. These varying conditions of the thalamus necessarily lead to corresponding alterations in the mutual relation of the different carpels which compose an apocarpous pistil, and modify very materially the appearance of different flowers.

FIG. 407.

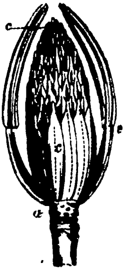


FIG. 408.

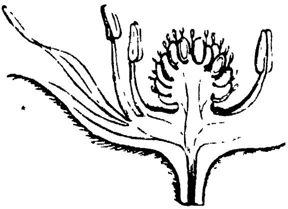


FIG. 409.

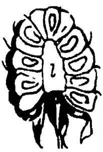


Fig. 40 . Central part of the flower of the Tulip-tree (*Liriodendron tulipi-ra*). The thalamus, *a*, is more or less cylindrical. *c, c.* Carpels. ens.——*Fig.* 408. Section of the flower of the Strawberry. The thalamus is nearly hemispherical, and bears a number of separate carpels on its upper portion.—— *Fig.* 409. Section of the ripe pistil of the Raspberry, showing the conical thalamus, *l*.

2. *Syncarpous Pistil.*—We have already seen, in speaking of the floral envelopes and andrœcium, that the different parts of which these whorls are respectively composed may be distinct from each other, or more or less united. From the position of the carpels with respect to one another, and from their nature, the latter are more frequently united than any other parts of the flower. This union may take place either partially, or entirely, and it may commence at the summit, or at the base of the carpels. In the former case, as in *Xanthoxylon fraxineum* (*fig.* 411), the carpels are united by their stigmas only; in *Dictamnus Fraxinella* (*fig.* 427) the upper parts of their styles are united; while in the *Labiatæ* (*fig.* 412, *s*), and most *Boraginaceæ* (*fig.* 413, *d*), the whole of the styles are united. In all these cases the ovaries are distinct, and in many *Boraginaceæ* the stigmas also; but in all *Labiatæ* the stigmas are distinct.

It is far more usual to find the carpels united by their lower portions or ovaries, and this union also may take place to various extents. In the Rue (*fig.* 414, *ov*) the union only takes place at the base of the ovaries, the upper parts remaining distinct, in which case the ovary is commonly described as *lobed*. In *Dianthus* (*fig.* 405) the ovaries are completely united, the styles being distinct; while in the Primrose (*fig.* 367) the ovaries, styles, and stigmas are all united. When two or more ovaries are thus completely united so as to form one body, the organ resulting from their union is called a *compound* or *polycarpellary ovary*.

FIG. 410.

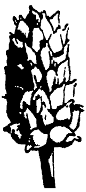


FIG. 411.

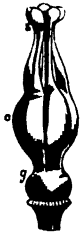


FIG. 412.

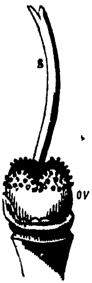


FIG. 413.

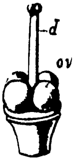


Fig. 410. Apocarpous pistil of the Pheasant's-eye (*Adonis*).——*Fig.* 411 Pistil of *Xanthoxylon fraxineum* supported on a gynophore, *g*. The ovaries, *o*, and styles are distinct, but the stigmas, *s*, are united.— –*Fig.* 412. Pistil of Horehound (*Marrubium vulgare*), a Labiate plant. Its ovaries, *ov*, are distinct, the styles, *s*, being united, and the stigmas distinct. *Fig.* 413. Pistil of *Myosotis*, a Boraginaceous plant. *ov*. Distinct ovaries. *d*. United styles.

Polycarpellary Ovary.—The compound ovary formed as just stated may either have as many cavities separated by partitions as there are component carpels, or it may have only one cavity. These differences have an important influence upon the attachment of the ovules, as will be seen later when speaking of placentation. If we consider three free carpels placed as in *fig.* 415, *a*, each of these possesses a single cavity corresponding to its ovary, so that if we make a transverse section of the whole (*fig.* 415, *b*), we necessarily have three cavities, each of which is separated from those adjoining it by two walls, one being formed by the side of its own ovary and the other by that of the one next to it. But if these three carpels, instead of being distinct, are united by their ovaries, as in *fig.* 416, *a*, so as to form a single ovary, the latter must necessarily also have as many cavities as there are component carpels, *b*, and each cavity must be separated from those adjoining it by a wall which is called a *dissepiment* or *partition*. Each dissepiment must be also composed of the united sides of the two adjoining ovaries, and be consequently double.

In the normal arrangement of the parts of the ovary, it will necessarily happen that the styles (when they are distinct) must alternate with the dissepiments, for as the former are prolongations of the apices of the blades of the carpellary leaves, while the latter are formed by the union of their margins, the dissepiments have the same relations to the styles as the sides of the blade of a leaf have to its apex; that is, they must be placed right and left of them.

FIG. 414.

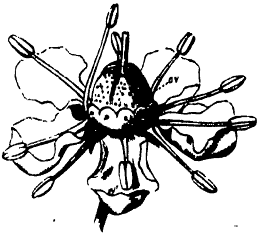


FIG. 415.

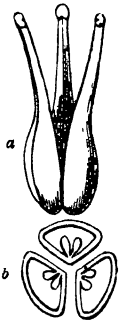


FIG. 416.

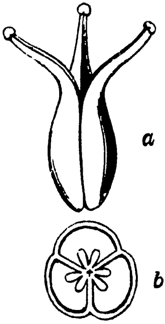


Fig. 414. Flower of the Rue (*Ruta graveolens*), showing the ovaries, *ov*, united at their bases.——*Fig.* 415. *a*. Diagram of three carpels placed side by side, but not united. *b*. A transverse section of the ovaries of the same.——*Fig.* 416. *a*. Diagram of three carpels united by their ovaries, the styles and stigmas being free. *b*. A transverse section of the ovaries of the same.

The cavities of the compound ovary are called *cells* or *loculi*, and such an ovary as that just described would be therefore termed *three-celled* or *trilocular*, as it is formed of three united ovaries. All dissepiments which are not formed by the united walls of adjoining ovaries are termed *spurious* or *false*. It follows, therefore, that a single carpel can have no true dissepiment, and is hence, under ordinary and normal circumstances, *unilocular* or *one-celled*.

From the preceding observations it follows that when ovaries which are placed side by side cohere, as in *fig.* 416, and form a compound ovary, the dissepiments must be vertical, and equal in number to the ovaries out of which that compound ovary is formed. When a compound ovary is composed, however, of more than one whorl of ovaries, placed in succession one over the other, as in the Pomegranate, horizontal true dissepiments may be formed by the ovaries of one whorl uniting by their bases with the apices of those placed below them (*fig.* 551).

We have just observed that all dissepiments are said to be spurious except those which are formed by the union of the walls of contiguous ovaries, and it occasionally happens that such spurious dissepiments are formed in the course of growth, by which the ovary acquires an irregular character. These false dissepiments commonly arise from projections of the placentas inwards; less frequently by ingrowths from some other parts of the walls of the ovaries. Some of these are horizontal, and are called *phragmata*, as in *Cassia fistula* (*fig.* 417), where the ovary, after fertilisation, is divided by a number of transverse dissepiments, which are ingrowths from its walls. Others are vertical, as in Cruciferous plants, where the dissepiment, called a *replum* (*fig.* 418, *cl*), is formed from the placentas. Another case is that of *Datura Stramonium*, where the ovary is formed of two carpels, and is hence normally two-celled; but, instead of remaining bilocular, it becomes four-celled below (*fig.* 419) from the formation of a spurious vertical dissepiment. This dissepiment does not extend to the top of the ovary, so that the upper portion of the latter is only two-celled (*fig.* 420). In the

FIG. 417.

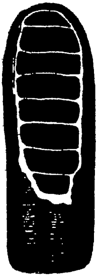


FIG. 418.

FIG. 419.

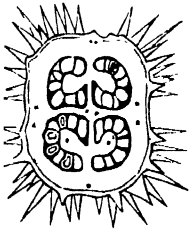


FIG. 420.

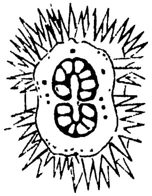


Fig. 417. Vertical section of a portion of the mature ovary of *Cassia fistula*, showing a number of transverse spurious dissepiments (*phragmata*).——*Fig.* 418. Vertical section of the ovary of the Wallflower *ov*. Ovules, each attached by a stalk to the placenta. *cl*. Vertical spurious dissepiment called the replum.——*Fig.* 419. Transverse section of the lower part of the ovary of the Thorn-apple (*Datura Stramonium*), showing that the ovary is here four-celled. *Fig.* 420. Transverse section of the same ovary at its upper part, showing that it is here two-celled.

Gourd tribe (*fig.* 548), also, spurious dissepiments appear to be formed in the ovary in a vertical direction by projections from the placentas. In the Flax, again (*fig.* 421), spurious incomplete vertical dissepiments are formed in the ovary by projections from the dorsal sutures. In the ovary of *Astragalus* (*fig.* 422), also, a spurious dissepiment is formed by a folding inwards of the dorsal suture; while in those of *Oxytropis* and *Phaca* (*fig.* 423) a spurious incomplete dissepiment is produced by a folding inwards of the ventral suture.

It should be noticed that in our description of spurious dissepiments we have not confined our attention to those of compound ovaries alone, but have also referred to those of simple ovaries, in which they sometimes arise. The spurious dissepiments of *Cassia fistula*, *Astragalus*, *Phaca*, and *Oxytropis* are all examples of such formations in simple ovaries.

FIG. 421.

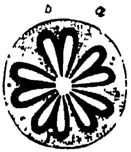


FIG. 422.

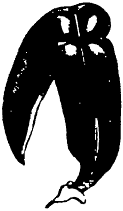


FIG. 423.

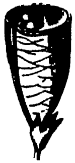


Fig. 42 . Transverse section of the ovary of the Flax (*Linum usitatissimum*), showing five complete and true dissepiments, *a*, and five incomplete spurious dissepiments, *b*.——*Fig.* 422. Transverse section of the mature ovary of *Astragalus*, showing spurious dissepiment proceeding from the dorsal suture.——*Fig.* 423. Transverse section of the mature ovary of *Phaca*.

Polycarpellary ovaries containing only one cavity are generally constructed in a manner essentially the same as those already described, except that the edges of the constituent carpels are either not turned inwards at all or not sufficiently far to meet in the centre of the ovary, so that all their cavities communicate in the centre. An ovary formed in either of these ways is unilocular though compound, as in the Orchis (*fig.* 425) and Poppy (*fig.* 426).

We turn now to examine in more detail the separate parts of the carpellary sporophylls, which, we have seen, are the ovary, style, and stigma.

1. THE OVARY.—The ovary, as already mentioned, may be *simple* or *compound*, the latter when it is composed of two or more

ovaries combined together. The terms simple pistil and simple ovary are not in all cases synonymous terms; a pistil is only said to be simple (*figs.* 396 and 406) when it is formed of but one carpel, the terms pistil and carpel being then mutually convertible; but an ovary is simple, as just noticed, whether it forms part of a simple pistil, as in Leguminous plants generally (*fig.* 406), or of one of the carpels of an apocarpous but polycarpellary or compound pistil, as in the Stonecrop (*fig.* 284).

Generally speaking, the ovary is *sessile* upon the thalamus, the carpellary leaves out of which it is formed having no stalks. In rare cases, however, the ovary is more or less elevated above the outer whorls, when it is said to be *stalked* or *stipitate*, as in *Dictamnus* (*fig.* 457, *g*) and *Dianthus* (*fig.* 405, *g*); this stalk has received the name of *gynophore*.

Fig. 424.

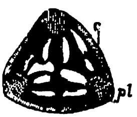


Fig. 425.

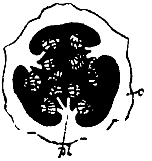


Fig. 426.

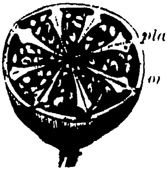


Fig. 424. Transverse section of the one-celled ovary of Mignonette (*Reseda*) c. The lower flattened portion or ovary of one of the three carpels of which it is formed. *pl.* One of the three parietal placentas.——*Fig.* 425. Transverse section of the one-celled ovary of an Orchis. *c* The lower portion or ovary of one of the three carpels of which it is formed, slightly infolded. *pl.* One of the three parietal placentas.——*Fig.* 426. Transverse section of the ovary of a species of Poppy *ov.* Ovules. *plac.* Placentas, which in the young ovary nearly meet in the centre, and thus the ovary becomes almost many-celled, but as the ovary progresses in development it is only one-celled.

The ovary, whether simple or compound, may be either united with the receptacular tube or free from it. In the former case, as in the Myrtle (*fig.* 273), it is *inferior* or *adherent*, and the calyx is *superior*; in the latter, as in *Dictamnus* (*fig.* 427), it is *superior* or *free*, and the calyx is *inferior*. In some flowers the ovary is but partially adherent to the receptacle, as in the species of Saxifrage (*fig.* 428), in which case it is sometimes termed *half-adherent* or *half-inferior*; and the calyx is then said to be *half-superior*; the latter terms are, however, but rarely used, the ovary being generally described as inferior, whether its adhesion to the receptacle be complete or only partially so, and *vice versa*.

Some doubt has been entertained in many cases as to the true nature of the external tubular portion. It has been regarded in some as part of the calyx; but in others, as in the Gooseberry, it is a hollowed receptacle, or thalamus, the true calyx springing from the top of the cup-shaped body, and the ovary being placed upon and adhering to the side of the latter. This relationship is seen more clearly in such apparently inferior ovaries as those of the Rose (*fig.* 429), where the thalamus, *r*, *r*, is certainly concave, and bears a number of carpels, *o*, *o*, on its inner walls. A longitudinal section will at once show the difference; in the Rose we find a single cavity open at its summit, and its walls covered with distinct carpels. The ovaries of the Rose are therefore superior or free.

FIG. 427.

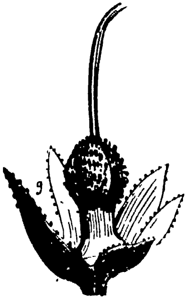


FIG. 428.

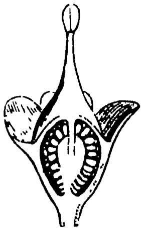


FIG. 429.

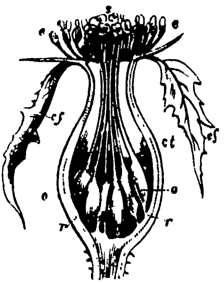


FIG. 430.

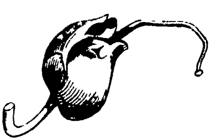


Fig. 427. Pistil of *Dictamnus Fraxinella.* The ovary is supported on a gynophore, *g*, and is superior. *Fig.* 428. Vertical section of the flower o[illegible]frage, showing the ovary partially adherent to the calyx.——*Fig.* 429. Vertical section of the flower of the Rose. *r*, *r*. Concave thalamus, upon which are placed several carpels, each of which is furnished with a style and stigma, *s*. *e*, *e*. Stamens.——*Fig.* 430 Compound irregular mature ovary of *Antirrhinum.*

The ovary varies much in form and in the character of its surface: when *simple* it is generally more or less irregular in form; but when *compound* it is commonly regular. Exceptions to the regularity of compound ovaries are not infrequent; an example may be seen in *Antirrhinum* (*fig.* 430). The compound ovary is generally more or less ovoid in form. The outer surface may be either perfectly even or uniform, showing no trace of its internal divisions; or marked by longitudinal furrows extending from its base to the origin of the style and corresponding to the points of union of its constituent carpels. When these furrows are deep, the ovary assumes a lobed appearance, and is described as *one-*, *two-*, *three-*, *four-*, *five-*, or *many-lobed*, according to the number of its lobes. Sometimes we find, in addition to the furrows which correspond to the lines of union of the ovaries, others of a more superficial character which correspond to the dorsal sutures. At the latter places, however, it is more usual to find slight projections, which then give a somewhat angular appearance to the ovary.

When the ovary is compound, the number of carpels of which it is composed may be ascertained in several ways. When the styles (*fig.* 416), or stigmas (*fig.* 346), remain distinct, their number generally corresponds to the number of the carpels. It happens, however, occasionally that the styles are themselves divided, as in *Euphorbia* (*fig.* 431), in which case they fail to indicate the number of carpels that are actually present. This may then be determined by the furrows or lobes on the external surface of the ovary, or the number of partitions or loculi which it contains, as these in nearly all cases correspond in number to the carpels of which that ovary is composed.

FIG. 431.

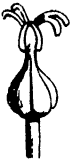


FIG. 432.

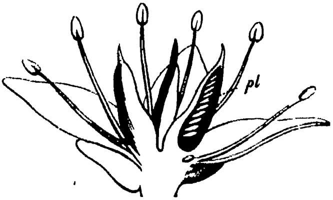


Fig. 431. Pistillate flower of a species of *Euphorbia*, with three forked styles.
Fig. 432. Vertical section of the flower of the Stonecrop. *pl.* Placenta of one of the ovaries, arising from the ventral suture.

The term *placenta* is commonly applied to the more or less marked projection to which the ovule or ovules are attached in the cavity of the ovary (*figs.* 398, *p*, and 432, *pl*). The placentas are variously distributed in the ovaries of different plants, but with very rare exceptions their position indicates the margin of the carpellary leaf or leaves. The term *placentation* is used to indicate the manner in which the placentas are distributed.

a. Kinds of Placentation.—In the monocarpellary ovary the placenta is usually situated along the ventral suture, or the line which corresponds to the union of the two margins of the blade of the carpellary leaf, out of which it is formed; such a placenta is therefore termed *marginal* (*figs.* 398, 399, and 432).

In compound ovaries we have three kinds of placentation:

namely, *axile*, *parietal*, and *free central.* The *axile* form occurs generally in compound many-celled ovaries. The carpellary-leaves are folded so completely that their edges meet in the centre, dividing the cavity of the ovary into as many loculi as there are carpels (*figs.* 415 and 416) and forming a central axial column, from which the term axile is derived. The placentas situated at their ventral sutures are arranged on the centre or axis, as in the Lily (*fig.* 433) and *Campanula* (*fig.* 434). In one Natural Order, the *Caryophyllaceæ*, the dissepiments or partitions formed by the inturned walls are destroyed or absorbed during the growth of the ovary, so that the axial body of placentas appears free. This constitutes a form of *free central* placentation.

FIG. 433.

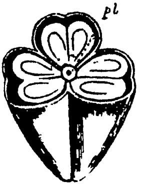


FIG. 434.

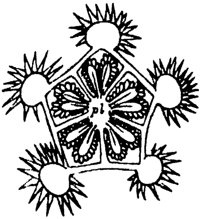


FIG. 435.

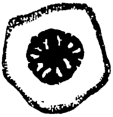


Fig. 433. Transverse section of the compound ovary of the Lily. The ovary is three-celled (trilocular). The placentas, *pl*, are axile or central.—*Fig.* 434. Transverse section of the ovary of a species of *Campanula*. The ovary is five-celled or quinquelocular, and the placentation, *pl*, axile. *Fig.* 435. Transverse section of the ovary of a species of *Cactus*. The ovary is one-celled, and the placentation parietal.

In a compound one-celled ovary the principal form of placentation is the *parietal.* The placentation is termed *parietal* when the ovules are attached to placentas placed either directly on the inner wall of the ovary, as in the Mignonette (*fig.* 424, *pl*) and Cactus (*fig.* 435), or upon incomplete dissepiments formed, as already noticed, by the partially infolded margins, as in the species of *Orchis* (*fig.* 425, *pl*) and Poppy (*fig.* 426, *plac*). In parietal placentation, the number of placentas corresponds to the number of carpels of which the ovary is formed, and their position to the edges of the carpellary leaves.

In some cases the placenta is formed upon the axis or thalamus, and not upon the sporophylls at all. The thalamus in this case projects upwards with the cavity of the ovary. The condition is seen, *e.g.*, in the *Primulaceæ* (*fig.* 438). Like the condition in the *Caryophyllaceæ*, this is known as *free-central* placentation. To this point we shall return later.

Besides the regular kinds of placentation just described, it sometimes happens that the ovules are placed more or less irregularly in the cavity of the ovary. In the Flowering Rush (*fig.* 439) they cover the whole inner surface of the carpels except the midribs, and the placentation is consequently described as *superficial*; in *Nymphæa*, the white Water-lily, they are attached all over the dissepiments; in *Cabomba*, they arise from the dorsal suture; and in the Broom-rapes (*Orobanche*) from placentas placed within the margins of the ventral suture.

FIG. 436.

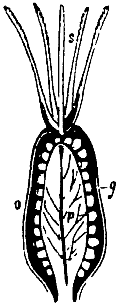


FIG. 437.

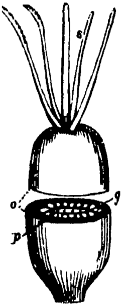


FIG. 438.

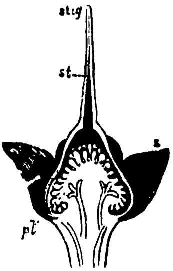


FIG. 439.

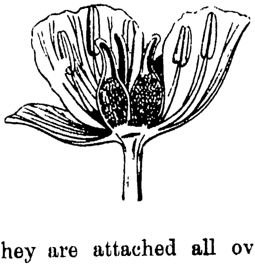


Fig. 436. Vertical section of *Cerastium hirsutum* (*Caryophyllaceæ*). *o.* Ovary. *p.* Free central placenta. *g.* Ovules. *s.* Styles and stigmas.——*Fig.* 437. Transverse section of the same with the two portions or sections separated. *o.* Ovary. *p.* Placenta. *g.* Ovules. *s.* Styles and stigmas. From Jussieu.——*Fig.* 438. Vertical section of the pistil of Cyclamen (*Primulaceæ*). *s.* Sepals. *pl.* Free central placenta. *st.* Style. *stig.* Stigma. *Fig.* 439. Vertical section of the flower of the Flowering Rush (*Butomus umbellatus*), showing the inner surface of the ovaries covered all over with ovules.

b. Origin of the Placenta.—The placenta is, in most cases at least, a cellular growth developed from the confluent margins of the carpels, or, more strictly speaking, from the confluent margins of the blades of the carpellary leaves. In some cases the placenta extends along the whole line of union of the carpel (*fig.* 431, *pl*); in others it may be confined to its base or apex. Each placenta is to be considered as composed of two halves, one half being formed by each margin of the carpel. In simple ovaries the placenta is developed by a single carpel. In compound many-celled ovaries the placentas are formed by the union of the inturned margins of the carpels at the centre of the ovary; while in compound one-celled ovaries presenting parietal placentation, each placenta is formed from the contiguous margins of two carpels which do not meet in the centre.

That in these forms of placentation the placentas are really developed from the margins of the carpels is proved in various ways. In the first place, in regular kinds of placentation the placentas always correspond to the lines of union of the margins of the carpel or carpels, and hence may naturally be considered as formed from them; and, secondly, we frequently find that in monstrosities or abnormal growths, where the carpel is developed in a more or less flattened condition, a placenta bearing ovules is formed upon each of the margins.

The origin of the free central placenta is not always the same; we have already seen that there are two different types recognisable. In the first, this also is a development from the margins of the carpels. The carpels of which the compound ovary is formed originally meet in the centre and develop placentas from their margins in the same manner as in ordinary axile placentation; subsequently the walls of the ovary grow more rapidly than the dissepiments, so that the connection between them is soon destroyed; and from this cause, and also from the great subsequent development of the placenta, the septa ultimately become almost or quite broken up, so that the placenta is left free from the cavity of the ovary. This view is strengthened by the fact that in several of the *Caryophyllaceæ* we often find dissepiments in the young ovary, and even traces of them at the lower part of the mature ovary; these are the remains of dissepiments which have become ruptured on account of the unequal development of the parts of the ovary. The second type is illustrated by the Primrose and many other plants, which have a free central placenta; in these no traces of dissepiments can be found at any period of the growth of the ovary. Duchartre and others, who have traced the development of the ovary in the *Primulaceæ*, state that the placenta is free in the centre from its earliest appearance, that it is originally a little papilla on the apex of the thalamus, and that the walls of the future ovary grow up perfectly free, and ultimately enclose it. The formation of such a free central placenta cannot therefore be well explained upon the marginal theory, as the carpels have never had any connection with it except at their bases. Nor is it necessary to suppose that a placenta is essentially of foliar origin. Since it has been established that the ovule is to be looked upon as the megasporangium of the flowering plant, it follows that it may be produced, as other sporangia are in some of the lower forms, either from the axis itself, or from foliar outgrowths from it (sporophylls). The case of the Yew, already referred to, is another instance of axial origin, the ovule being here naked and terminal. Other illustrations have been already given, and to them the case of the *Plumbaginaceæ* may be added. In *Armeria*, a genus of that Natural Order, the ovary, which is composed of five carpels, surrounds a single ovule, which, rising from the axis, is supported on a stalk which curves downwards at its apex, and suspends the ovule free in the centre of the cavity (*fig.* 440). Here, therefore, the ovule and placenta are developments of the axis.

FIG. 440.

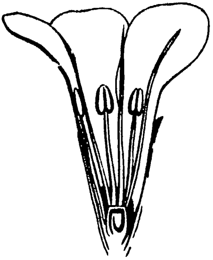


FIG. 441.

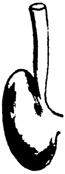


FIG. 442.

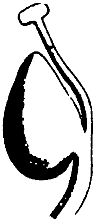


FIG. 443.

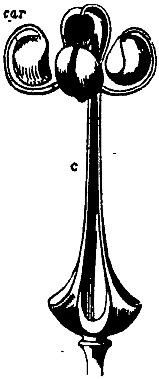


Fig. 440. Vertical section of the flower of *Armeria*. The ovary is seen to contain only a single ovule suspended from a funiculus or stalk. The ovule is here said to be reclinate.——*Fig.* 441. One of the carpels of the Strawberry with a lateral style.——*Fig.* 442. Carpel of *Alchemilla* with a basilar style. The stigma is capitate.——*Fig.* 443. The carpophore, *c*, of a species of Geranium with the rolled-back carpels, *car*.

From all that has now been stated, we may draw the following conclusions, namely:—that no single theory sufficiently accounts for the production of the placenta in all cases; but that the axile, parietal, and some forms of the free central placentation may be best explained on the foliar hypothesis; and that the formation of the free central placenta of the *Primulaceæ*, *Santalaceæ*, and some other plants, can only be satisfactorily accounted for by considering the placenta as a production of the axis.

In the majority of instances, we find one kind of placentation occurring throughout all the plants of a particular Natural Order. The *Scrophulariaceæ*, *Ericaceæ*, and *Campanulaceæ* present us with axile placentation; the *Papaveraceæ*, *Violaceæ*, and *Cruciferæ* with parietal; and the *Caryophyllaceæ*, *Santalaceæ*, and *Primulaceæ* with free central placentation. In some Natural Orders the placentation is not constant through all the genera.

FIG. 444.

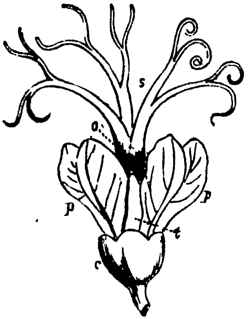


FIG. 445.

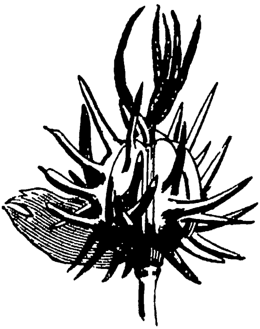


Fig. 444. Pistillate flower of one of the *Euphorbiaceæ*. *c.* Calyx. *p, p.* Petals. *t.* Membranous expansion round the ovary. *o.* Ovary with three styles. *s*, each of which is twice-forked.——*Fig.* 445. Ovary of the Castor-oil plant (*Ricinus communis*), belonging to the Euphorbiaceæ. The styles in this case are once-forked.

2. THE STYLE.—The style usually arises from the geometrical summit of the ovary, of which it is a continuation in an upward direction, as in the Primrose (*fig.* 395): it is then termed *apical*. In other cases, the apex of the ovary becomes inflected towards the side or base, from the carpel or carpels of which it is formed being folded like ordinary leaves in reclinate vernation; the style then becomes *lateral*, as in the Strawberry (*fig.* 441), or *basilar*, as in *Alchemilla* (*fig.* 442). In the two latter cases, therefore, the geometrical and

organic apices of the ovary do not correspond, as the point of origin of the style always determines the latter.

The style is generally directly continuous with the ovary, which gradually tapers upwards to it as in *Digitalis*; in such a case it is *persistent*, and forms a more or less evident part of the fruit; in other cases, however, there is a kind of articulation at the point where the style springs from the ovary, as in *Scirpus*, and then the style always falls off after the process of fertilisation is completed. It is then said to be *deciduous*, and has no connection with the fruit.

When the style is basilar or lateral, and the ovary to which it is attached more or less embedded in the thalamus, it frequently appears to spring from the latter; such an arrangement is called a *gynobase*, and the ovary is said to be *gynobasic*. The condition is seen in the *Labiatæ* (*fig.* 412) and the *Boraginaceæ* (*fig.* 413), the ovaries of which are free, but the styles, which spring from their bases, become connected and form a central column, which appears as if it were a prolongation of the thalamus.

FIG. 446.

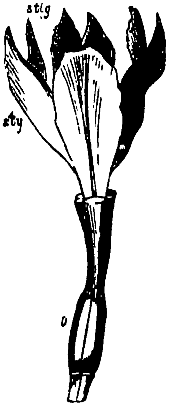


FIG. 447.

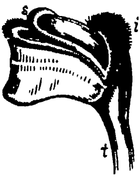


FIG. 448.

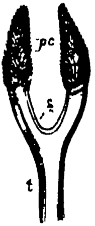


Fig. 446. Pistil of a species of *Iris*. *o*. Ovary. *sty*. Petaloid styles. *stig*. Stigmas.——*Fig.* 447. Upper part of the style and stigma of *Leschenaultia formosa*. *t*. Style. *i*. Collecting hairs. *s*. Stigma.——*Fig.* 448. Upper part of the style, *t*, of a Composite plant, dividing into two branches, which are covered above by collecting hairs, *pc*.

Such an arrangement must not be confounded with that of the ovaries and styles of the species of *Geranium* (*fig.* 443), and some other plants, where the axis itself is prolonged in the form of a beak-like process, to which the ovaries and styles become united, and from which they separate when the fruit is ripe. This prolongation of the thalamus is termed a *carpophore* (see page 146).

When the styles of a syncarpous pistil are distinct, they usually correspond to the number of carpels of which that pistil is composed. It sometime happens, however, that the style of each carpel bifurcates or becomes forked, as in some *Euphorbiaceæ*, either once (*figs.* 430 and 445), or twice (*fig.* 444); in which case the apparent number of the styles is double or quadruple that of the carpels.

Form and Surface of the Style.—In form the style is generally more or less cylindrical; either tapering from the base to the apex, as is generally the case, or becoming enlarged as it proceeds upwards. In other cases the style is filiform, or more or less thickened, or angular; and rarely thin, coloured, and flattened like a petal, as in the species of *Canna* and *Iris* (*fig.* 446), when it is said to be *petaloid*.

FIG. 449.

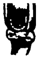


FIG. 450.

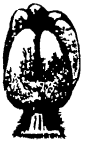


FIG. 451.

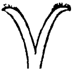


Fig. 449. Pistil of a Lily, with one style and a trilobate stigma.——*Fig.* 450. Lobed stigma of the Melon.——*Fig.* 451. Pistil of a species of *Chrysanthemum*, with one style and a bifid stigma, the divisions with hairs at their extremities.

The surface of the style may be either smooth, or covered in various ways with hairs. These hairs, when situated on the style, frequently serve the purpose of collecting the pollen, and are hence termed *collecting hairs*. The collecting hairs on the style of the species of *Campanula* are retractile. In the *Compositæ* the surface of the style is also more or less covered with stiff collecting hairs (*fig.* 448, *pc*); as the style is developed later than the stamens, it is at first shorter than these organs, but as the growth proceeds it pushes itself through the syngenesious anthers, and thus the hairs on its surface come in contact with the pollen and become covered with it. In some of the Orders allied to the Compositæ, the hairs form a little ring below the stigma (*fig.* 447, *i*).

3. **The Stigma.**—The stigma is a rough, usually sticky area, situated in various positions above the ovary, but generally occupying its pointed apex. In the case of a compound stigma, it usually shows rays or branches corresponding in number to the constituent carpels. The roughness is due to projecting cells of its external layer, while the stickiness is caused by the secretion of honey.

The stigmas of a syncarpous pistil are generally opposite to the cells, and alternate with the dissepiments, but it sometimes happens, as in the Poppy, that half the stigma of one carpel unites with a similar half of that of the adjoining carpel; the rays thus formed are alternate with the cells, and opposite to the dissepiments, the latter being, however, imperfect (*fig.* 426).[1]

Fig. 452.

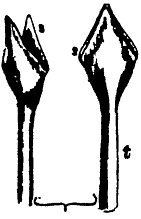


Fig. 453.

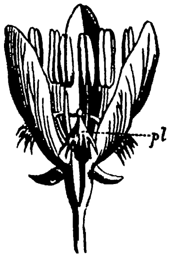


Fig. 452. Stigma, *s*, attached to style, *t*, of *Bignonia arborea*. In the left-hand figure the *lamellæ* are separate, in the other applied closely to each other.——*Fig.* 453. Flower of a species of *Rumex*, showing fringed stigmas, *pl*.

We have already seen that the stigma may be separated from the ovary by the style (*figs.* 395–397); or the latter organ may be absent, in which case the stigma is said to be *sessile*, as in the Barberry (*fig.* 398, *st*) and Poppy. In Orchids the stigma is sessile on the gynostemium, and appears as a little cup-shaped viscid space just below the attachment of the pollen-masses.

In a syncarpous pistil the stigmas may be either united together, as in the Primrose (*fig.* 395), or distinct, as in *Campanula* (*fig.* 333); in the latter case, instead of looking upon these separate parts as so many distinct stigmas, it is usual to describe them as if they were portions of but one; we then speak of the stigma as *bifid*, *trifid*, &c., or as *bilobate*, *trilobate*, &c., according to the number and character of its divisions. The term *lobe* is usually applied when the divisions are thick, as in the Lily (*fig.* 442) and Melon (*fig.* 450); when these are flattened and somewhat strap-shaped, as in the *Compositæ* (*fig.* 541), the stigma is *fissured* or *cleft*; when flattened into plates or bands they are termed *lamellæ*, as in *Bignonia* (*fig.* 452) and *Mimulus*. The number of these divisions in the majority of instances corresponds to the number of carpels of which the pistil is composed; and if the latter organ is many-celled, the number of cells generally corresponds also to the divisions of the stigma. The five-cleft stigma of some Campanulas accordingly indicates that there are five cells to the ovary, and that the pistil is formed of five carpels. In the *Graminaceæ* (*fig.* 404) and *Compositæ* (*figs.* 448 and 451), however, we have a bifid stigma, and but one cell in the ovary.

The lobes assume different appearances: they may be smooth or thick and fleshy, as in the Melon (*fig.* 450), or feathery, as in many Grasses (*fig.* 404), or fringed or laciniate, as in the Dock (*fig.* 453, *pl*).

When the stigmas are united, the number of parts in the compound stigma is usually indicated by radiating furrows or grooves. When the stigmas unite and form a compound body upon the top of the style, this compound stigma is said to be *capitate*. In the Violet (*fig.* 456) the stigma presents an irregular hooded appearance.

FIG. 454.

FIG. 455.

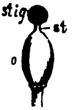


FIG. 456.

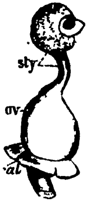


Fig. 454. *s.* Peltate or shield-shaped stigma surmounting the style, *t*, of a species of *Arbutus*.——*Fig.* 455. Pistil of *Daphne*. *o.* Ovary. *st.* Style. *stig.* Stigma.——*Fig.* 456. Pistil of Pansy (*Viola tricolor*). *cal.* Remains of calyx. *ov.* Ovary. *sty.* Style, surmounted by an irregular hooded stigma.

THE FLOWER-BUD. ÆSTIVATION OR PRÆFLORATION.

The mode in which the different parts of the flower are disposed in the flower-bud is termed their *æstivation* or *præfloration*. The terms used in describing æstivation refer especially to the relative positions of the component parts of the calyx and corolla, because the stamens and carpels, from their peculiar forms, can give us no such arrangements of their parts as are exhibited by the more or less flattened floral envelopes.

In describing the varieties of æstivation, we have to include: 1st, the disposition of each of the component parts of the floral envelopes, considered independently of the others; and 2nd, the relation to one another of the several members of either of the floral envelopes taken as a whole. With regard to the disposition of each of the component parts of the floral envelopes considered independently of the others, the same terms are used as in similar varieties of vernation, with the addition of the *crumpled* or *corrugated* form, which is not found in the parts of the leaf-bud. This latter arrangement may be seen in the petals of the Poppy (*Papaver*) and Rock Rose (*Helianthemum*); it derives its name from the parts being irregularly contracted into wrinkled folds.

With respect to the relation to one another of the several members of either of the floral envelopes taken as a whole, various arrangements occur, all of which may be classified in two divisions: namely, the *Circular* or *Valvate*, and the *Imbricated.*

FIG. 457.

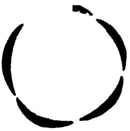


FIG. 458.

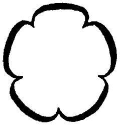


FIG. 459.

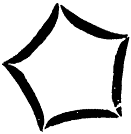


FIG. 460.

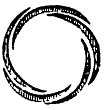


Fig. 457. Diagram to illustrate valvate æstivation.——*Fig.* 458. Diagram to illustrate induplicate æstivation.——*Fig.* 459. Diagram to illustrate reduplicate æstivation.——*Fig.* 460. Diagram to illustrate contorted or twisted æstivation.

1. *Varieties of Circular Æstivation.*—We distinguish three well-marked varieties of circular æstivation, i.e. the *valvate*, *induplicate*, and *reduplicate*. The *valvate* (*fig.* 457) may be seen in the calyx of the Lime, and in that of *Guazuma ulmifolia*; in this variety the component parts are flat or nearly so, and in contact by their margins throughout their whole length without any overlapping. This variety of æstivation may be generally distinguished, even when the flowers are expanded, by the margins of its component parts being slightly thickened, or at all events not thinner than the rest of the organ; whereas in all varieties of imbricated æstivation the overlapping margins are usually thinner, as may be well seen in the sepals of the species of *Geranium*. When the component sepals, or petals, instead of being flattened, are folded inwards at the points where they come in contact (*fig.* 458), the æstivation is *induplicate*, as in the petals of *Guazuma ulmifolia*, and in the sepals of some

species of *Clematis*. When the margins are turned outwards under the same circumstances (*fig*. 459), the æstivation is *reduplicate*, as in the sepals of the Hollyhock (*Althæa rosea*) and some other plants of the Natural Order *Malvaceæ*; also in the petals of the Potato.

2. *Varieties of Imbricated or Spiral Æstivation.*—We distinguish five varieties of this kind of æstivation, i.e. the *imbricate*, *convolute*, *quincuncial*, *cochlear*, and *vexillary*. The true *imbricate* æstivation, as seen for instance in the calyx of *Camellia japonica* (*fig*. 461), is formed by the component parts overlapping each other more or less by their margins, like the tiles on the roof of a house. Usually, when there are five leaves in the floral whorl, one is overlapped on both margins, the next one is completely external, and each of the other three overlaps the leaf next it on one side and is overlapped by that next it on the other (*fig*. 461).

FIG. 461.

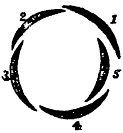


FIG. 462.

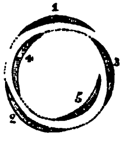


FIG. 463.

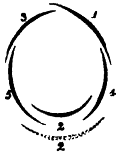


FIG. 464.

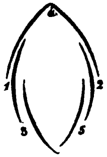


Fig. 461 Diagram to illustrate imbricate æstivation. The figures, 1, 2, 3, 4, 5, show that the successive parts are arranged in a spiral manner.——*Fig*. 462. Diagram to illustrate quincuncial æstivation. 1 and 2 are external, 4 and 5 internal, and 3 is partly external and partly internal.——*Fig*. 463. Diagram to illustrate cochlear æstivation.——*Fig*. 464. Diagram to illustrate vexillary æstivation. 1 and 2 form the alæ or wings, 3 and 5 the carina or keel, 4 the vexillum. (See *Papilionaceous Corolla*.)

When one margin of each leaf overlaps the one next it, and the other margin is overlapped by the leaf on the other side of it, so that the whole whorl presents a more or less twisted appearance, the æstivation is *contorted*; if the overlapping is considerable, it is said to be *convolute*, as in the corolla of the Mallow (*fig*. 460). When the parts of a floral whorl are five in number, and these arranged in such a manner that there are two parts placed on the outside, two inside, and the fifth overlapping one of the internal by one margin, while it is itself overlapped on its other margin by one of the external parts, the æstivation is said to be *quincuncial* (*fig*. 462). Familiar examples of this form are afforded by the corolla of the Rose and the calyx of the Bindweed (*Convolvulus sepium*). In this kind of æstivation a spiral arrangement of the parts is well seen, and is indicated in the diagram (*fig.* 462) by a dotted line. The spiral cycle thus formed, which is the normal one in *pentamerous* or *quinary* flowers (those with the parts in fives), and which occurs in the majority of Dicotyledons, corresponds to the $\frac{2}{5}$, *pentastichous*, or *five-ranked* arrangement of leaves. When, instead of the wholly internal leaf being next to the wholly external one, it is the next but one, a variety of æstivation occurs to which the name *cochlear* has been given (*fig.* 463). Familiar examples of this are afforded by the Snapdragon (*Antirrhinum majus*) and other allied plants. Another marked modification of imbricated æstivation occurs in the corolla of the Pea and other Papilionaceous flowers, where the superior petal, which is generally the largest and is called the *vexillum*, is folded over the others which are arranged face to face (*fig.* 464). This kind of æstivation is commonly termed *vexillary*.

It frequently happens that the calyx and corolla exhibit different kinds of æstivation. In *Guazuma ulmifolia* the calyx is *valvate*, and the corolla *induplicate*. In plants of the Natural Order *Malvaceæ* the calyx is *valvate* or shows some form of circular æstivation; and the corolla is *twisted*. In the Corn Cockle (*Githago segetum*), the species of St. John's Wort (*Hypericum*), the *Geranium*, and many other plants, the calyx is *quincuncial* or *imbricate*, and the corolla *twisted*.

The kinds of æstivation above described are always constant in the same species, and frequently throughout entire genera and even Natural Orders; hence they are of great importance in systematic botany.

The term *anthesis* is sometimes used to indicate the period at which the flower-bud opens.

Besides the definite and constant relations which the parts of the floral envelopes have to one another in the flower-bud, they have also a definite and constant relation in the same plant to the axis upon which they are placed. In describing these positions we use the terms *anterior*, *posterior*, and *lateral*. We call that part *posterior* which is turned towards the axis; and that next the bract from the axil of which the flower arises, *anterior*. When there are four leaves in a whorl, one will be *anterior*, one *posterior*, and two *lateral*, as in the sepals of the Wallflower. If there are five we have two arrangements. In the calyx of the order *Leguminosæ*, two sepals are *posterior*, two *lateral*, and one *anterior*, while in the corolla one petal is *posterior*, two *anterior*, and two *lateral* (*figs.* 303 and 464). In plants of the order *Rosaceæ* we have a precisely contrary position exhibited by the parts of the two floral envelopes; here we have two sepals *anterior*, two *lateral*, and one *posterior*; while in the corolla there are two petals *posterior*, two *lateral*, and one *anterior*.

The same definite relation with respect to the axis also holds good in many cases in the staminal and carpellary whorls, by which important distinctive characters are frequently obtained. In floral diagrams it is usual to indicate the position of the axis upon which the flower is placed by a dot placed over the posterior part of the diagram.

The Ovule.

As the anther has been shown to be comparable to a sorus consisting of four or more sporangia, so we may regard each placenta with its ovules as having a similar morphological value. In the anther the sorus forms a single body, or *synangium*, while in the pistil the separate ovules or megasporangia are free. Some botanists, however, prefer to look upon the placenta as bearing a number of sori instead of corresponding to a single one. In their view each ovule corresponds to a sorus of *Azolla*, which contains a single megasporangium; and the indusium of the latter is represented by the integuments of the ovule. The latter may, however, be a special protective coating for the ovule without being comparable to an indusium, from which indeed they differ in being developed from the body of the sporangium, and not from the surface of the sporophyll.

An ovule consists of an ovoid body, which in section shows the parts represented in *fig.* 469. There is a central mass of tissue which constitutes the bulk of the structure, and is called the *nucellus*. This is surrounded by certain coats or integuments which grow up round it and enclose it, with the exception of a small canal or passage at the apex. This passage is known as the *micropyle*. In the interior of the nucellus is a conspicuously large cell with thin walls, which is the *megaspore* or *embryo-sac*. The megaspore never lies free in the interior of the sporangium, as do the microspores already described. It is always from the first surrounded closely by the tissue of the nucellus, and in its growth it absorbs the whole or a good deal of the latter: in some cases encroaching even upon the substance of the integuments. Sometimes more than one megaspore is produced, but this is unusual. Only one comes to maturity in such cases.

The ovule is either attached directly to the placenta, when it is said to be *sessile* (*fig.* 436, *g*); or indirectly by a stalk called the *funiculus* or *funicle* (*figs.* 418, *ov*, and 440), when it is described as *stalked*. The point of attachment of the ovule to the placenta if sessile, or to the funiculus when stalked, is termed the *hilum*.

Some ovules, as those of the Mistletoe (*fig.* 466), consist simply of the nucellus, *n*, and its megaspore, *c*, as above described, in which case the nucellus is termed *naked* (*fig.* 465); but in almost all plants it becomes enclosed in one or two coats. In the Walnut there is but one coat, which appears at first as a little circular process around its base; this gradually increases in size, and by growing upwards ultimately forms a sheath or cellular coat to the nucellus, which it entirely closes except at the apex, where a small opening may be always observed (*fig.* 467, *end*). There is only one coat formed in the *Compositæ*, *Campanulaceæ*, *Lobeliaceæ*, and some other orders.

FIG. 465.

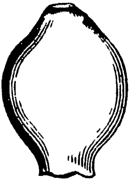


FIG. 466.

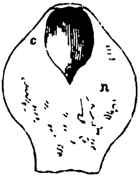


FIG. 467.

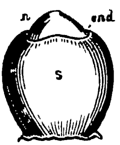
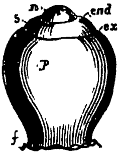


FIG. 468.



g. 465. Ovule of the Mistletoe (*Viscum album*), consisting of a nake nucellus.—*Fig.* 466. The same ovule cut vertically to show the embry sac. *c*, in the nucellus, *n*.—*Fig.* 467. Ovule of the Walnut (*Juglans regia* n. Projecting end of the nucellus. *s*. Coat covering the nucellus excep t the foramen, *end*.—*Fig.* 468. Ovule of a species of *Polygonum*. *f*. En of ovule where it is attached to the placenta. *p*. Primine. *s*. Secundin x. Exostome. *end*. Endostome. *n*. Projecting end of the nucellus.

In most plants, however, the ovule has two coats, in which case we observe two circular or annular processes around the base of the nucellus, the inner one being first developed; these processes continue to grow upwards as before described, until they also ultimately form two sheaths or coats, which entirely enclose the nucellus except at its apex (*fig.* 468). The inner coat is at first seen to project beyond the outer, but the latter ultimately reaches and encloses it. The inner coat is usually termed the *secundine* (*figs.* 468, *s*, and 469, *c*), and the outer the *primine*; some botanists prefer to follow the order of development of the coats, and consequently term the inner coat the *primine*, and the outer the *secundine*, reversing the order of the names. Others, to prevent confusion, more properly term the inner coat, or secundine, the *integumentum internum*; and the outer coat, or primine, the *integumentum externum*. The orifice left at the apex of the nucellus, as in the former instance where only one coat is present, is called the *micropyle*. The openings in the two coats commonly correspond to each other, but it is sometimes found convenient to distinguish them by distinct names; that of the outer is then called the *exostome* (*fig.* 468, *ex*); that of the inner, the *endostome* (*end*).

In some cases a third coat is indicated, which grows up later from the base of the ovule and encloses it more or less loosely. This is known as an *arillus*. It is generally associated more closely with the seed, in connection with which it will be discussed.

FIG. 469.

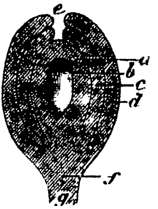


FIG. 470.

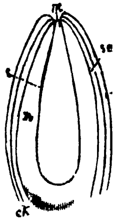


FIG. 471.

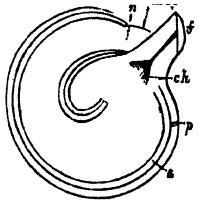


Fig. 469. Section of an ovule (diagrammatic). *a.* Nucellus. *b.* Embryo-sac. *c.* Inner coat. *d.* Outer coat. *e.* Micropyle. *f.* Chalaza. *g.* Funiculus or funicle.——*Fig.* 470. Vertical section of the orthotropous ovule of *Polygonum*. *ch.* Chalaza. *prim.* Primine. *sec.* Secundine. *n.* Nucellus. *s.* Embryo-sac. *m.* Micropyle.——*Fig.* 471. Vertical section of a campylotropous ovule of Wallflower (*Cheiranthus*). *f.* Funiculus. *ch.* Chalaza. *p.* Primine. *s.* Secundine. *n.* Nucellus. *mic.* Micropyle.

The nucellus and its coat or coats are intimately connected at one point, called the *chalaza* (*figs.* 470, *ch*, and 471, *ch*); but at the other parts of the ovule they are more or less distinct. This chalaza is the point where the vessels pass from the placenta, or, when the ovule is stalked, from the funiculus, into the ovule, for the purpose of affording nourishment to it; it is generally indicated by being coloured, and of a denser texture than the tissue by which it is surrounded. Through the micropyle the pollen-tube usually reaches the megaspore, as will be hereafter fully described.

RELATION OF THE HILUM, CHALAZA, AND MICROPYLE TO ONE ANOTHER.—When an ovule is first developed, the point of union of its coats and nucellus, called the chalaza, is at the base or hilum, close to the placenta or funiculus; in which case a straight line would pass from the micropyle through the axis of the nucellus and its coats to the hilum. In rare instances this relation of parts is preserved throughout its development, as in the *Polygonaceæ* (*fig.* 470), when the ovule is termed *orthotropous*, *atropous*, or *straight*. In such an ovule, therefore, the micropyle, *m*, is situated at its geometrical apex, or at the end farthest removed from the hilum; while the chalaza, *ch*, is placed at its base.

In a second class of ovules the relative position of parts is exactly the reverse of that of orthotropous ones—hence such are called *anatropous* or *inverted* ovules. This arises from greater growth on one side than the other, the body of the nucellus remaining straight. It thus becomes completely inverted, so that the chalaza (*fig.* 473, *ch*) is removed from the hilum, *h*, to the geometrical apex of the ovule; the micropyle, *f*, being at the same time turned towards the hilum, *h*. In anatropous ovules a connection is always maintained between the chalaza and the hilum by means of a vascular cord or ridge called the *raphe* (*fig.* 473, *r*), which is the elongated funiculus adherent to the ovule. This raphe or cord of nutritive vessels passing from the placenta or funiculus, and by its expansion forming the chalaza, is generally situated in anatropous ovules on the side which is turned towards the placenta or funiculus. Anatropous ovules are very common; examples may be found in the Dandelion (*fig.* 478), Apple, and Cucumber.

FIG. 472.

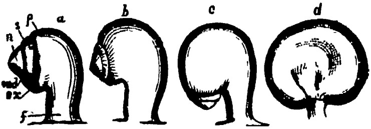


Fig. 472. The campylotropus ovule of the Mallow in its different stages of development. From Le Maout. In *a* the curvature is commencing, in *b* it is more evident, in *c* still more marked, and in *d* it is completed. *f.* Funiculus. *p.* Primine. *s.* Secundine. *n.* End of nucellus. *ex.* Exostome. *end.* Endostome.

Besides the two kinds of ovules mentioned above, there is another kind, more rarely met with, which is intermediate between the orthotropous and anatropous forms; to it the term *amphitropous* has been applied. In this ovule, which is also called *heterotropous* or *transverse*, the hilum, *f*, is on one side, and the micropyle, *m*, and chalaza, *ch*, are placed transversely to it (*fig.* 474), and therefore parallel to the placenta. In this case the hilum is connected to the chalaza by a short raphe, *r*.

It sometimes happens, however, that the nucellus of the ovule, instead of being straight as in the above instances, becomes more or less curved. In the Wallflower (*fig.* 471), and other plants of the order to which it belongs, as well as in the *Caryophyllaceæ* and many other orders, the apex of the ovule becomes gradually turned downwards towards its base, and is ultimately placed close to it, so that the whole nucellus is bent upon itself, and a line drawn from the micropyle, *mic*, through the axis of the nucellus, *n*, and its coats, would describe a curve; hence such ovules are called *campylotropous* or *curved*. In these ovules, the chalaza, *ch*, and hilum are close to each other as in orthotropous ones, but the micropyle, *mic*, instead of being at the geometrical apex of the ovule, is brought down close to the hilum or base. The progressive development of the campylotropous ovule is well seen in the Mallow, as represented in *fig.* 472, *a*, *b*, *c*, *d*. This kind of ovule is evidently formed by one side of the nucellus developing more extensively than the other, so that the micropyle is pushed round to the base.

FIG. 473.

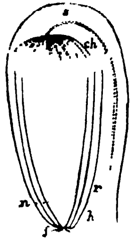


FIG. 474.

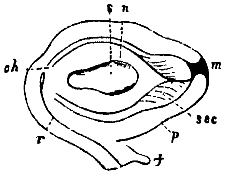


Fig. 473. Vertical section of the anatropous ovule of the Dandelion. *h.* Hilum. *f.* Micropyle or foramen. *n.* Nucellus. *s* Base of the nucellus. *ch.* Chalaza. *r.* Raphe.——*Fig.* 474. Longitudinal section of the amphitropous or transverse ovule of *Lemna trisulca* *f.* Funiculus. *n.* Nucellus. *p.* Primine. *sec.* Secundine. *s.* Embryo-sac *ch.* Chalaza. *r.* Raphe. *m.* Micropyle. From Schleiden.

The ovules of Angiospermous plants are enclosed in an ovary (*fig.* 436). Those of the Gymnosperms, including the *Coniferæ*, *Cycadaceæ*, and allied orders, are always exposed without this covering. In *Cycas* they are situated on the margins of peculiarly metamorphosed leaves; in the *Coniferæ* they are formed at the bases of indurated bracts or scales (*fig.* 475); in *Taxus* they are borne at the ends of certain branches. In some Angiosperms the seeds become partially exposed in the course of the development of the ovary into the fruit, the apex of the ovary opening and disclosing them in its cavity. This takes place in the Mignonette (*fig.* 509), *Leontice*, and *Cuphea*. These must not be confused with Gymnospermous plants, in which the ovules are naked from their first formation.

Number and Position of the Ovules.—a. *Number.*—The number of ovules in the ovary, or in each of its cells, varies in different plants. In the *Polygonaceæ*, *Compositæ*, *Thymelaceæ*, and *Dipsaceæ*, the ovary contains but a solitary ovule; in the *Umbelliferæ* and *Araliaceæ*, there is but one ovule in each cell. When there is more than one ovule in the ovary, or in each of its cells, the number may be either few and easily counted, when the ovules are said to be *definite*, as in *Æsculus* (*fig.* 480),—and the ovary or cell is then described as *biovulate*, *triovulate*, &c.—or the ovules may be very numerous, when the ovary is *multiovulate* and the ovules *indefinite*, as in *Cerastium* (*fig.* 436, *g*).

Fig. 475.

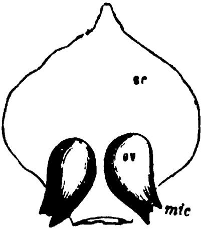


Fig. 476.

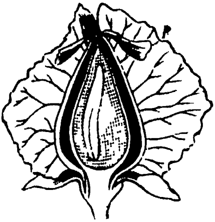


Fig. 475. Bract or carpellary leaf, *sc*, of a species of *Pinus*, bearing two naked ovules, *ov*, at its base. *mic*, Micropyle or foramen.——*Fig.* 476. Vertical section of the fruit of a species of *Rumex* (*Polygonaceæ*). *p.* Enlarged calyx surrounding the fruit. The fruit contains a single erect orthotropous seed. The position of the ovule in the ovary is also described as erect and orthotropous. The embryo is inverted or antitropous.

b. *Position.*—The position of the ovules with regard to the cavity or cell in which they are placed is also liable to vary. When there is but one ovule, this may arise at the bottom of the ovary or cell and be directed towards the summit, as in *Compositæ* and *Polygonaceæ* (*fig.* 476), when it is said to be *erect*; it may be inserted at the summit of the ovary and be turned downwards, as in

Hippuris (*fig.* 477), in which case it is *pendulous*; if it is attached a little above the base, and directed obliquely upwards, as in *Parietaria* (*fig.* 478), it is *ascending*; if, on the contrary, it arises a little below the summit, and is directed obliquely downwards, as in the Mezereon (*fig.* 472) and Apricot, it is *suspended*; if from the side of the ovary, without turning upwards or downwards, as in *Crassula*, it is *horizontal* or *peltate*. In some plants, as in *Armeria* (*fig.* 440), the ovule is suspended from the end of a long funiculus arising from the base of the ovary; such an ovule is frequently termed *reclinate*.

In the cases mentioned the position of the ovule is usually constant, and hence this character assumes considerable importance in distinguishing genera, and even Natural Orders. In the *Compositæ*, for instance, the solitary ovule is always erect; while in the allied orders, the *Valerianaceæ* and *Dipsaceæ*, it is suspended or pendulous. In the *Polygonaceæ* (*fig.* 476), the ovule, which springs from the axis, is also always solitary and erect; and in the *Thymelaceæ* (*fig.* 479) it is suspended. On the other hand, in some Natural Orders we find its position varying in different genera, although generally constant in the same genus; in the *Rosaceæ*, for instance, the genera *Geum* and *Alchemilla* have an ascending, while *Poterium* and *Sanguisorba* have a suspended ovule, and in *Potentilla* both are found. In the *Ranunculaceæ* also we find the ovule varying as regards its position.

FIG. 477.

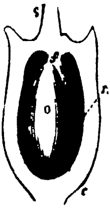


FIG. 478.

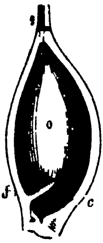


FIG. 479.

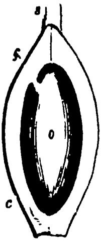


FIG. 480.

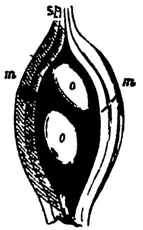


Fig. 477. Vertical section of the ovary of the Mare's Tail (*Hippuris vulgaris*). *o.* Ovule, which is inverse or pendulous, and anatropous. *s.* Base of the style. *f.* Funiculus. *r.* Raphe. *c.* Chalaza.——*Fig.* 478. Vertical section of the ovary of the Pellitory (*Parietaria officinalis*), with a single ascending ovule. The letters have the same references as in the last figure. *Fig.* 479. Vertical section of the ovary of the Mezereon (*Daphne Mezereum*), containing a solitary suspended ovule. The letters refer as before. From Jussieu.——*Fig.* 480. Vertical section of a cell of the ovary of a species of *Æsculus* containing two ovules, *o*, *o*, one of which is ascending and the other suspended. *m*, *m*. The micropyle or foramen in the two ovules. *s.* Base of the style. From Jussieu.

When the ovary or cell has two ovules, these may be placed side by side at the same level and have the same direction, as in

Nuttallia, when they are said to be *collateral*; or they may be placed at different heights; if then they follow the same direction, they are said to be *superposed*; if not, one ovule may be ascending and the other suspended, as in *Æsculus* (*fig.* 480). The position of the ovules in those cases where they are in definite numbers is also usually constant and regular, and similar terms are employed; but when the number of ovules in the ovary or cell is indefinite, the relations are less constant, and depend in a great measure upon the shape of the cell and the size of the placentas. In the long ovaries of many of the *Leguminosæ* and *Cruciferæ* (*fig.* 417), the ovules are superposed, and, not crowding each other, they are all turned in the same direction. In other cases the ovules are numerous, and having been developed in a small space, they necessarily press against each other, and acquire irregular forms and varying positions according to the direction of the pressure. In describing these varying positions the same terms are used as those referred to when speaking of the relations of the solitary ovule. These terms are also applied in the same sense to the relations of the seed in the pericarp.

SECTION III.

SEXUAL REPRODUCTIVE ORGANS.

Our study of the reproductive processes of plants so far has been confined to the *sporophyte* and its asexual cells the *spores*; we must now turn to the alternate phase or form of the plant, the *gametophyte*, and its sexual cells the *gametes*. These can give rise to a new individual only after coalescence in pairs. The process of their coalescence is known as *conjugation* when the two gametes are indistinguishable from each other, or *fertilisation* when they are not alike. The body formed by the coalescence is called a *zygote*. These sexual cells never arise on the sporophyte, but on the other phase of the plant, the gametophyte. The latter, in some of the Algæ and Fungi, bears gonidia or asexual cells as well, the structure and mode of origin of which present no features different from those already described.

The phase of the plant which we have called the gametophyte is seen most prominently in the lower forms, diminishing in size and degree of differentiation as we ascend the scale. The sporophyte can be recognised in only a few of the Algæ and Fungi, is of nearly the same dimensions as the gametophyte in the Mosses, and above this group assumes a preponderance and becomes the conspicuous form of the plant, while the gametophyte dwindles almost to the point of suppression.

In the Algæ the gametophyte may be filiform, or take the form of a plate of cells, or assume large dimensions, showing much morphological differentiation. Often in this group the sporophyte cannot be recognised at all. Where asexual cells occur in such cases, they are gonidia, and are developed upon the gametophyte. Instances of the occurrence of the sporophyte among the Algæ are afforded doubtfully by certain of the cystocarps in the Red Seaweeds, and more certainly in some of the *Chlorophyceæ* (*Coleochæte*) by a small multicellular body developed from the zygote, the cells of which all give rise to zoospores.

In the Fungi the gametophyte is always the prominent form. It bears both gonidia and gametes, but the latter in some cases are not functional. The parasitic habit of life of many of these plants is attended by a general degradation of both form and structure, which especially marks the reproductive organs. In some cases the production of sexual cells by the gametophyte has disappeared. Such a gametophyte is called a *potential* one. Its true nature can be recognised only by a comparison with other forms which bear both kinds of reproductive cells. The sporophyte can be seen in such forms as *Mucor* (*fig.* 487), where the zygote on germination produces a small promycelium, and doubtfully in certain Ascomycetes, where it may be represented by the ascocarp. A very rudimentary condition of it is shown by *Cystopus* (*fig.* 489), where the zygote produces a number of zoospores after a period of rest.

In the Mosses and their allies the gametophyte is still the prominent form, the sporophyte being represented by the complex sporogonium. Above the group of the Thallophyta, the nature of any phase of the plant body can be recognised by tracing its origin. The gametophyte is always the product of the germination of the spore, and where it has undergone much reduction this is the only clue to its identity. In the series of forms above the Ferns we find cases in which it becomes more and more closely attached to the spore, ultimately being altogether enclosed in it.

Those plants which are heterosporous exhibit two forms of gametophyte, one developed from the microspore, the other from the megaspore: both are inconspicuous.

In the isosporous or homosporous Ferns and in the Horsetails the gametophyte is always thalloid. In the former group each gametophyte usually produces gametes which are female and others which are male, the former developed in organs called *archegonia*, and the latter in others known as *antheridia*; in the Horsetails it generally gives rise to one or the other, but not to both. We have thus in the Horsetails potential though not actual heterospory. In the heterosporous Ferns the relative development of the two forms of gametophyte becomes unequal, and this difference may be seen throughout the higher plants. In *Salvinia* the male gametophyte is a small tubular structure, produced by the outgrowth of the inner coat of the spore. It forms at its apex an antheridium consisting of an incomplete wall and two internal cells, each of which gives rise to two antherozoids or male gametes. In *Marsilea* and *Selaginella* the microspore gives rise to a small, somewhat oval, multicellular body, which produces antherozoids in its internal cells.

FIG. 481.

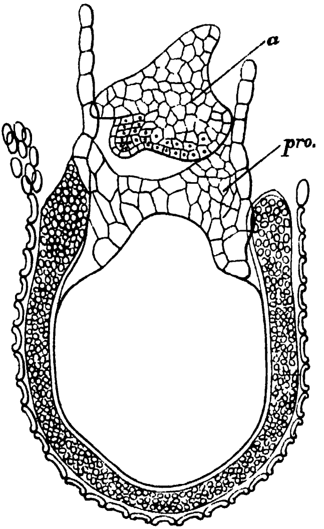


Fig. 481. Gametophyte produced by the megaspore of *Salvinia*. *pro.* Prothallium bearing *a*, young sporophyte. After Pringsheim.

The female gametophyte also shows a gradual degeneration. In *Salvinia* the megaspore bursts at its apex (*fig.* 481), and the prothallium is developed as a curiously shaped green body, the greater part of which remains within the spore. The free part bears the archegonia. In *Selaginella* and *Isoëtes* the development is still more markedly endosporous. The prothallium is developed inside the megaspore (*fig.* 482), which does not open till the former is well advanced; in some cases, indeed, until the archegonia are mature and the oospheres, or female gametes which they contain, are ready for fertilisation.

The Phanerogams, whose sporophytes have been treated of at considerable length in the preceding pages, have, as we have seen, two kinds of spore, the pollen grains or microspores and the embryo-sacs or megaspores. Each kind produces its appropriate gametophyte. The pollen grain gives rise on germination to a tubular structure something like that of *Salvinia*, but it does not bear an antheridium. Two gametes are produced in each tube which are altogether undifferentiated except in three species of Gymnosperms (*Cycas*, *Zamia*, and *Ginkgo*).

The embryo-sac or megaspore, on germination, produces a gametophyte in its interior. This is a further development of the process of endosporous formation of the prothallium which we have seen indicated in *Salvinia* and *Selaginella*. The germination of the megaspore takes place in the interior of the sporangium or ovule, from which, indeed, it is never set free. In the Gymnosperms the gametophyte consists of a large number of cells; while its morphological nature was not understood, it received the name *endosperm*, which still continues to be applied to it (*fig.* 483). In the Angiosperms it is very much reduced, consisting, when mature, of only a few cells or masses of protoplasm, some of which have no cell-wall (*fig.* 484). In the Gymnosperms the archegonia, usually several in number, are well developed, and are much like those of *Selaginella*. In the Angiosperms there is no archegonium, and a single oosphere lies free in the cavity of the spore (*fig.* 484, *oos*), being

FIG. 482.

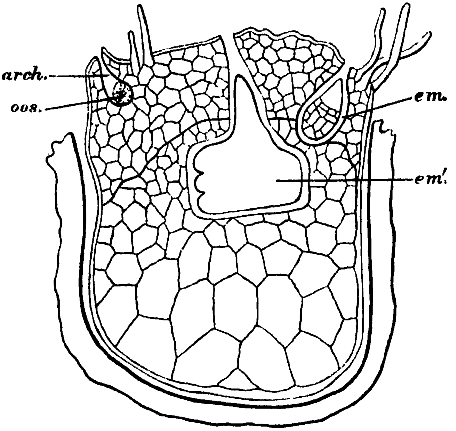


Fig. 482. Germination of megaspore of *Selaginella*. After Pfeffer. *arch.* Archegonium. *em*, *em'*. Young embryos. *oos.* Unfertilised oosphere.

hardly distinguishable from the other cells which are near it. After fertilisation in these plants, the gametophyte undergoes a further development, the cavity of the spore becoming filled by a tissue bearing the name of *endosperm*. This is, however, not morphologically comparable to the tissue bearing the same name in the Gymnosperms, which is developed before differentiation of the sexual cells, and is morphologically the same structure as the prothallium of the higher Cryptogams. Its exact nature is for the present undetermined.

FIG. 483.

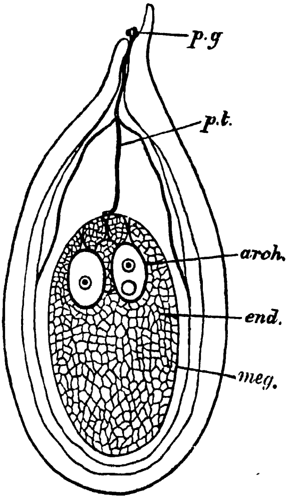


FIG. 484.

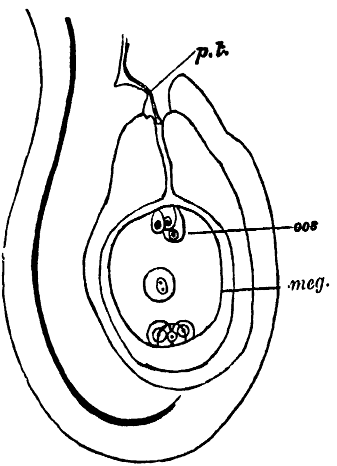


Fig. 483. Megasporangium (ovule) of *Pinus* at maturity. After Dodel Port. *meg.* Megaspore. *end.* Gametophyte or prothallium. *arch.* Archegonia. *p.g.* Pollen-grain or microspore, which has been transported to the micropyle of the ovule and has put out its prothallium, the pollen-tube, *p.t.* *Fig.* 484. Megasporangium (ovule) of an Angiosperm. *meg.* Megaspore. *oos.* Oosphere. *p.t* Pollen-tube.

The Gametes.

In the lowliest Algæ the gametes are not very different in appearance from the zoogonidia which the same plants produce, and are liberated in large numbers from the cells in which they originate (*fig.* 485). They are somewhat pear-shaped masses of protoplasm, without any protective coat, and are motile by means of two long tails or flagella of protoplasm, which spring from the narrow end of each mass. There is no difference between the gametes of such plants, which are consequently called *isogamous*. In certain other isogamous Algæ (*fig.* 486) the gametes are produced singly in each cell, and are then of greater dimensions, and are not furnished with flagella. These are not discharged into the water, as are the flagellate ones. The body arising from the fusion of the gametes of isogamous plants at once secretes round itself a delicate cell-wall, and is called a *zygospore*.

FIG. 485.

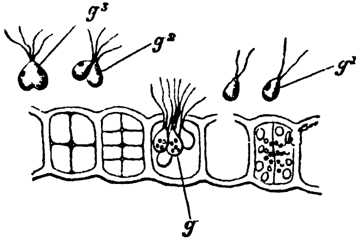


Fig. 485. Part of a filament of *Ulothrix* from which the gametes, *g*, are escaping. *g*¹. Free gamete. *g*², *g*³. Gametes conjugating.

In others of the Algæ the gametes begin to show a greater degree of differentiation. In some species of *Ectocarpus*, though they are externally similar, certain of them come to rest much earlier than the others. In *Cutleria* they are of two sizes; they all swim

FIG. 486.

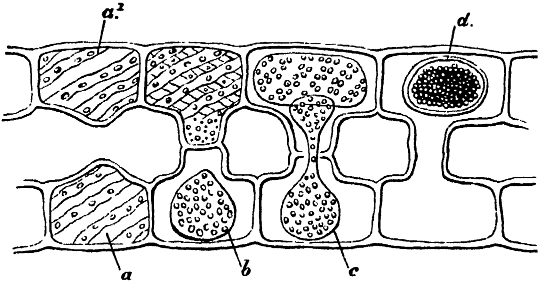


Fig. 486. Conjugation in *Spirogyra*. Two filaments are lying side by side, and from cells opposite to each other protuberances are growing out to meet. *a*, *a*¹. Each produces a gamete, *b*. When the protuberances have met and fused, one gamete passes over and unites with the other, *c*. *d*. Adult zygospore.

about on their being liberated from the plant, but the larger soon come to rest, while the smaller maintain their power of motion much longer. In this plant the gametes of different dimensions are developed in receptacles or gametangia of different form. The more active ones are held to be male;

those which soonest lose their motility, female. Plants with such gametes are called *heterogamous*.

FIG. 487.

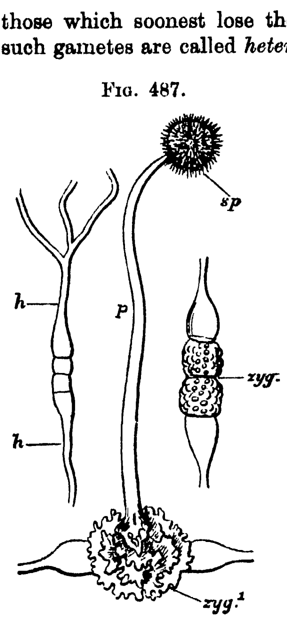


Fig. 487. Conjugation in *Mucor Mucedo*. *h*. Two hyphæ which have come into contact at their apices, and each has cut off from itself a cell. *zyg*. Zygospore resulting from the fusion of these cells. *zyg.*^{1} Adult zygospore after germination. *p*. Promycelium bearing a sporangium, *sp*.

In the lowliest Fungi, such as *Mucor*, we have gametes produced on special branches of the mycelium (*fig*. 487). These are undifferentiated masses of protoplasm which are never set free, but coalesce in consequence of the fusion of the cells in which they are formed.

In plants which are higher in the scale than those mentioned we find two kinds of gametes distinctly recognisable, which are truly male and female.

FIG. 488.

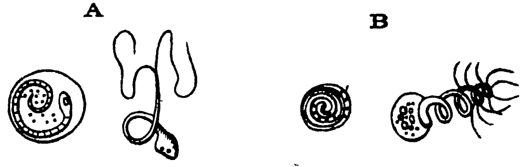


Fig. 488. A. Antherozoids of Moss (× 1200). B. Antherozoids of Fern (× 700).

The male gamete in the Cryptogams which live under such conditions that the coalescence of the sexual cells is brought about through the medium of water is generally a free-swimming piece of protoplasm, furnished with cilia or flagella like those of the gametes of isogamous plants (*fig*. 488). The shape is usually clavate or filamentous, and with very few exceptions these gametes have no cell-wall. They are known as *antherozoids*. In most Red Seaweeds they have no cilia, and become clothed with a cell-wall after their liberation from the gametophyte. In certain of the Fungi, especially the Lichens, similar bodies occur, which always have a cell-wall. Both these are frequently called *spermatia*, to distinguish them from the motile forms. There is some doubt as to the true nature of the spermatia in the latter group, many botanists inclining to the view that they are gonidia, and not gametes.

Throughout the groups of the Mosses and Vascular Cryptogams the ciliated antherozoid is always found (*fig.* 488). It is known to occur also in a few genera of the Gymnosperms, *Cycas*, *Zamia*, and *Ginkgo*.

FIG. 489.

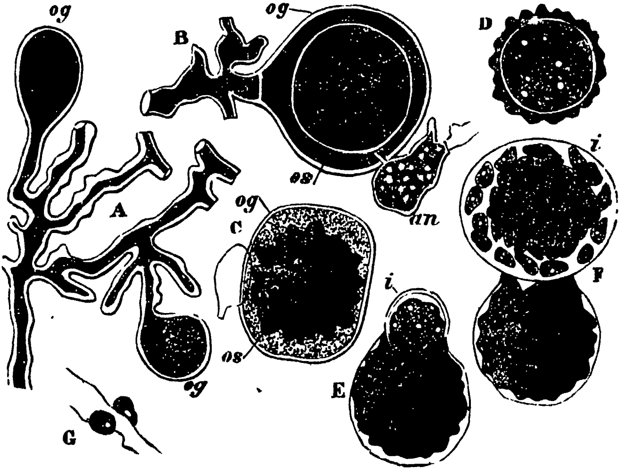


Fig. 489. A. Branched mycelium of *Cystopus* with young oogonia, *og*, *og*. B. Portion of mycelium bearing oogonium, *og*, with the oosphere, *os*; and antheridium or pollinodium, *an*. C. Mature oogonium, with *os*, the oospore. D. Mature oospore. E, F. Formation of swarm-spores or zoospores, G, from the oospores. *i*, *i*. Protruded endospore. After De Bary.

In other forms in which the coalescence does not take place by means of water, the male gamete is only a mass of undifferentiated protoplasm, usually of very small size. It never escapes from the seat of its formation until conditions are such as to enable it at once to coalesce with the female gamete. This form is found in many Fungi, such as *Cystopus*, and in all the Phanerogams with the exceptions already mentioned. It is always naked, never having a cell-wall apart from that of the cell in which it is formed (*fig.* 489).

The female gamete does not show so much variation. Its typical form is that of an ovoid or spherical mass of protoplasm without cell-wall or cilia, and it is termed an *oosphere*. It may escape from the gametophyte, as in *Fucus* (*figs.* 495 and 496), or it may remain where it is formed, and become fused there with the male gamete, which reaches it in various ways, as will be described later. In the Red Seaweeds it is not differentiated at any time.

The product of the coalescence of differentiated dissimilar gametes is termed an *oospore*. It immediately clothes itself with a cell-wall. Both zygospores and oospores are sometimes termed *zygotes*.

The Gametangia.

As the structures in which the spores are produced are called generally sporangia, so the term *gametangia* may be applied to those bodies in which the gametes are formed.

In isogamous plants the gametangia, like the gametes, are indistinguishable from each other. In most cases the gametangium is a single cell of the filament, showing no difference from any of the other cells. Sometimes the contents of the gametangium divide up into a large number of gametes (*fig.* 485); in other cases the whole of its protoplasm becomes rounded up into a single one (*fig.* 486).

A similar absence of differentiation marks the gametangia of some of the heterogamous forms. Usually, however, those which give rise to antherozoids are very different from those which produce oospheres. The former are generally called *antheridia*, the latter *oogonia* or *archegonia*, the last named being the most complex in structure.

The antheridium is usually a somewhat ovoid body, composed of several cells; it is often stalked, and in some cases furnished with a kind of lid. In *Chara* it is globular and of very complex structure. In the lower plants it is unicellular in many cases, and may then produce a single antherozoid. In certain of the Fungi it takes the form of a somewhat club-shaped branch of the mycelium, and is called a *pollinodium* (*fig.* 489, *an*). In *Salvinia* it is the apex of a tube-like outgrowth from the microspore. In the Angiosperms, where again the gametophyte springing from the microspore is a long tubular outgrowth, the antheridium is not differentiated.

The gametangium producing the oospheres is in some cases an oogonium, in others an archegonium. The former is unicellular, and may, as in *Volvox*, be hardly distinguishable from any other cell of the plant. In other cases it is an ovoid or spherical body, often mounted on a stalk. It usually produces one oosphere, and this often remains in it until fertilisation. In *Fucus* (*figs*. 493–496) it contains eight oospheres which are released by a rupture of the oogonium wall, and come into contact with the antherozoids after their escape. In *Chara* (*fig*. 490, *s*) the oogonium is surrounded by an investment of cells which enclose it, except at the apex.

FIG. 490.

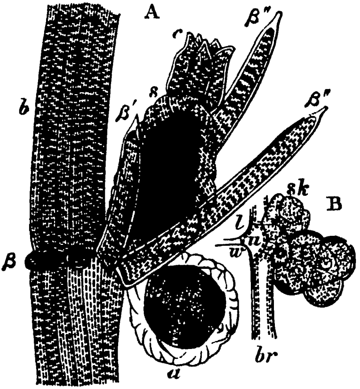


FIG. 491.

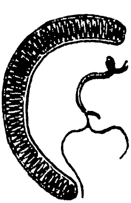


FIG. 492.

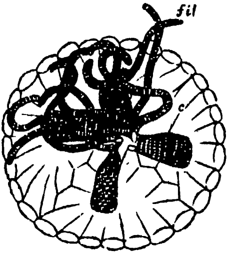


Fig. 490. A. Portion of the axis of *Chara fragilis*. *s*. Nucule or oogonium. *a*. Globule or antheridium. *b*. Internode. *c*. Crown or corona of nucule. β. Abortive leaves. β', β'', β''. Sterile leaflets. B. *sk*. Nucule, and *a*, globule, both in an early stage of development. *w*. Nodal cell of leaf. *u*. Union cell between it and basal node of globule. *l*. Cavity of internode of leaf. *br*. Cells of leaf covered with cortex. After Sachs.——*Fig*. 491. A portion of a filament, *fil*, of *fig*. 492, in the cells of which the antherozoids are developed; with a 2-ciliated *antherozoid* by its side.—— *Fig*. 492. A globule cut in half to show the oblong cells or manubria, *c*, and the separate filaments, *fil*. After Henfrey.

In plants above the Thallophytes the female gametangium is an archegonium. It is multicellular, and consists of a swollen basal portion or *venter* containing the oosphere, and surmounted by a *neck* or narrow portion, the length of which varies in different groups of plants (*fig*. 497).

A good deal of difference in completeness of differentiation of the gametangium is found in different groups. Its reduction reaches its greatest extent in the Angiosperms, where the archegonium is apparently unrepresented, or represented only by the oosphere, the latter being one of the few cells to which the gametophyte is reduced, all of which lie in the inside of the megaspore. In such Fungi as possess an oogonium (*fig.* 489, *og*) it is rudimentary, and consists only of a swollen head at the

FIG. 493.

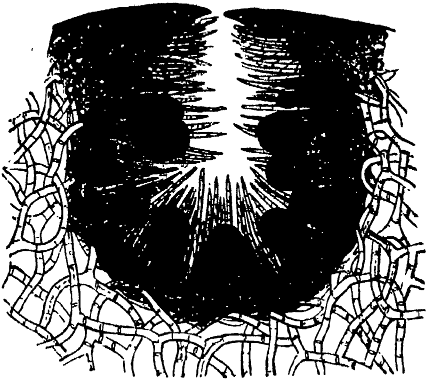


FIG. 494.

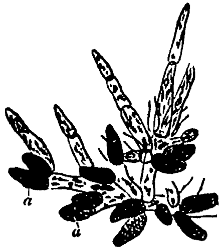


FIG. 495.

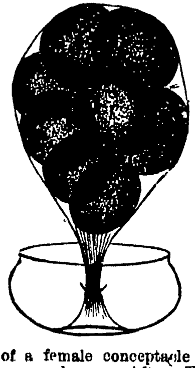


FIG. 496.

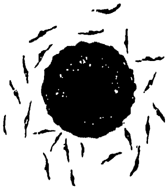


Fig. 493. Vertical section of a female conceptacle of *Fucus vesiculosus* containing oogonia and paraphyses. After Thuret.——*Fig.* 494. Antheridia, *a*, *a*, on the branched hairs of the male conceptacle. After Thuret.——*Fig.* 495. Oogonium with the oospheres fully differentiated and disengaging themselves from their coverings. After Thuret. ——*Fig.* 496. An oosphere surrounded by a number of antherozoids, one of which ultimately fuses with it.

end of a special branch, from which frequently both oogonium and pollinodium arise.

In the Red Seaweeds the female organ, as we have seen, contains no differentiated oosphere. It is a unicellular or multicellular structure known as a *procarp* (*fig.* 498, *pr*), and consists of a slightly swollen basal portion, prolonged upwards into a filament called the *trichogyne*, which is the part which fuses with the spermatium in fertilisation. The procarp does not open, but when the spermatium comes into contact with the trichogyne, the parts of the cell-walls which are touching become absorbed, and the contents of the spermatium pass into the procarp through the opening. A somewhat similar arrangement is described for certain of the Fungi, where it is called an *archicarp*.

FIG. 497.

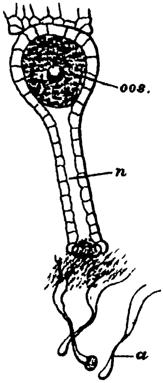


FIG. 498.

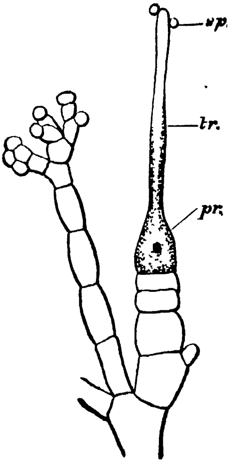


Fig. 497. Archegonium of a Liverwort (*Marchantia*). *n.* Neck. *oos.* Oosphere. *a.* Antherozoids.——*Fig.* 498. Procarp of one of the Red Seaweeds. *tr.* Trichogyne. *sp.* Spermatia. After Kny.

The position of the gametangia varies in different plants; in some they may occur on any part of the plant body, which gives no indication of special differentiation with a view to their occurrence; in others, particularly those whose gametophyte shows complexity of structure, they are confined to particular portions which are modified in a way that suggests the sporophore or inflorescence of the differentiated sporophyte. The greatest specialisation is shown in certain of the thalloid

Liverworts (*figs.* 499 and 500), where both antheridia and archegonia are borne upon special erect branches of the thallus. These differ in form: the antheridial receptacle is a body with a flattened head, on the upper surface of which the antheridia are placed in narrow pit-like depressions; the archegonia occur on the under side of a similar vertical receptacle, which shows radiating rib-like branches spreading out from the axis. The archegonia are here surrounded by modified leaves constituting the *perichætium*. A less evident specialisation is seen in the Mosses and Ferns. Generally in the former, both antheridia and archegonia occupy the summit of special leaf-crowned branches, and are surrounded by hairs of curious form known as *paraphyses* (*fig.* 501). In the latter the sexual organs are generally confined to a thickened portion of the prothallium, extending centrally along the under side and known as the *cushion*.

FIG. 499.

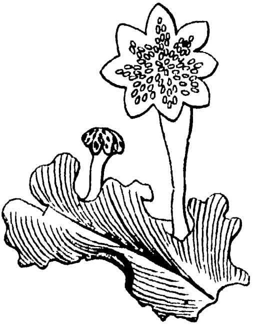


FIG. 500.

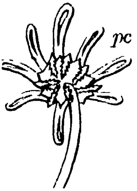


Fig. 499. Portion of the thallus of *Marchantia* bearing antheridial branch.——*Fig.* 500. Archegonial branch of *Marchantia*. *pc.* Perichætium.

In such of the Algæ as show a differentiation of their body, simulating stem and leaf, the gametangia are borne upon those portions which resemble the latter. In *Fucus* and its allies, in which the plant body is a thalloid shoot, there are special terminal collections of them, each being formed of a number of almost closed depressions or pits, known as *conceptacles* (*figs.* 5 and 493). In some species each conceptacle contains both antheridia and oogonia, in others only one or the other kind.

In consequence of the generally slight morphological differentiation of the gametophyte as compared with the sporophyte, we find a somewhat different distribution of the reproductive organs in the two cases. As we have seen, the sporangia are usually borne upon leaves which may be highly specialised or may be almost indistinguishable from the foliage leaves. The occurrence of axial sporangia is much less common, though, as we have seen, it is met with in many very diverse groups. On the other hand, the gametangia are much more generally axial in origin, rarely being found on leaves, and then on those which are not highly specialised.

In the Mosses and Ferns and their allies the sporophyte is at its origination always attached to the gametophyte, in consequence of the zygote germinating without being set free from the archegonium. The spore is, however, always detached from the sporophyte before germination. This is not the case in the Phanerogams, where, from the mode of its development, the megaspore always remains in the sporangium. The microspore in these plants is, on the other hand, always set free.

FIG. 501.

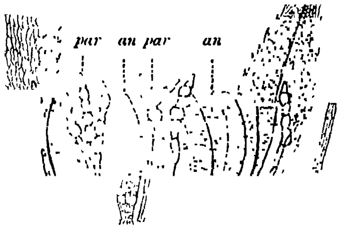


Fig. 501. Vertical section through apex of male plant of a Moss, *Mnium hornum* (×40). *an.* Antheridia. *par.* Paraphyses.

As we have thus cases in which the gametophyte, which bears the female cell, is developed in the spore while the latter remains in the sporangium, and others in which the spore escapes before the gametophyte arises from it, we find two methods of fertilisation which are characteristic of those respective groups.

Where the spore produces the gametophyte after liberation from the sporangium, fertilisation takes place by a free-swimming antherozoid making its way to an archegonium, down the neck of which it passes to the oosphere. Where the megaspore remains attached to the plant its prothallium or gametophyte is inaccessible to antherozoids, and these are therefore not developed. The microspore is carried by various agencies to the tissue either of the megasporangium itself as in the Gymnosperms, or to the sporophyll or carpel which bears the megasporangium (ovule) as in the Angiosperms. The prothallium produced from the microspore, which we have seen is a long tubular outgrowth known as the pollen-tube, bores its way through the tissue on which it finds itself and makes its way into the interior of the megaspore, now containing its gametophyte (*figs.* 483 and 484, *p.t.*). The male gamete fuses with the oosphere, forming a zygote, as in other cases. As usual, the latter surrounds itself with a cell-wall. In the Angiosperms it very shortly afterwards divides into two cells, of which the upper one becomes the *suspensor*, consisting of a chain of cells in consequence of repeated transverse divisions. The lower develops into the *embryo* or young sporophyte. In the Gymnosperms the suspensor and the embryo are produced somewhat similarly, but from only part of the zygote. The embryo, after a short period of active growth, becomes quiescent and remains inside the spore for a considerable period. The megaspore, still enclosed in its sporangium, now contains the gametophyte and the young sporophyte to which the latter has given rise, and constitutes the body which is called the *seed*. No further development takes place until the latter becomes detached from the parent sporophyte.

In some of the Gymnosperms the process is somewhat different. There are several archegonia in the prothallus or endosperm, and each contains its oosphere. More than one may become fertilised, and consequently more than one young sporophyte may be originated. In many genera also the zygote gives rise to more than one embryo. This phenomenon is known as *polyembryony*. Though many embryos are thus produced, only one as a rule matures.

It is evident from the history of development that only such plants can produce seeds as have all the stages of the life of the gametophyte carried out while the latter is attached to the parent sporophyte.

CHAPTER III.

MORPHOLOGY OF THE FRUIT AND SEED.

THE FRUIT.

THE act of fertilisation not only stimulates the further development of the oosphere, but brings about changes in neighbouring parts which are not directly concerned in the sexual process. The parts so modified may belong to both gametophyte and sporophyte as in the Phanerogams, or to the gametophyte alone as in the Cryptogams. The gametophyte in the Angiosperms, as we have seen, undergoes changes, leading to the formation of the endosperm; the tissue of that part of the sporophyte in which it is embedded is also modified in various ways, especially, though not exclusively, the sporophyll or carpel in which the megasporangium is found. The structures resulting from any such development of the sporophyte form what is known as the *fruit.*

Among the structures which are often called fruits in the Cryptogams we must include such forms as the cystocarps of some of the Red Seaweeds, in which the wall of the structure is derived from certain cells which are in the immediate neighbourhood of the sexual gamete. Rudimentary forms of fruit may also be recognised in the Mosses. In these cases, however, the modified structure is always derived from the gametophyte, and is not morphologically comparable to the fruit of the Phanerogams.

It is, however, in the group of the Phanerogams that we find the greatest variety of fruit, which we must now examine in some detail.

Changes in the Pistil during the development of the Fruit.

The fruit, being generally the ovary after a certain amount of development or alteration, should correspond with the latter in its structure. This is often the case, and the fruit consists of the same parts as the ovary, but in a modified condition. The walls of the ovary commonly alter in texture, and either become dry, membranous, coriaceous, woody, &c.; or, on the contrary, more or less pulpy, fleshy, &c.

In other cases more important changes take place during the ripening of the ovary which disguise the real mode of construction of the fruit. These changes arise either from the addition, abortion, or alteration of parts.

1st. The addition of parts is commonly produced by the formation of the spurious dissepiments already alluded to. In *Datura Stramonium*, for instance, we have a two-celled ovary converted into an imperfectly four-celled fruit by the formation of a spurious vertical dissepiment (*figs.* 419 and 420); this dissepiment appears to be formed by the projection of the placentas on the two sides, which meet and become united to corresponding projections from the dorsal sutures. In *Cassia fistula* (*fig.* 417), again, and some other fruits of a similar nature, we have a one-celled ovary converted into a many-celled fruit by the formation of a number of transverse dissepiments. In *Pretrea zanguebarica*, a one-celled ovary is converted into a six-celled fruit (*fig.* 502) by an extension and doubling inwards of the placenta. In *Tribulus terrestris* the ovary is five-celled; but as it approaches to maturity, each cell (*figs.* 503 and 504) becomes separated into as many divisions as there are seeds contained within it, in consequence of a corresponding number of projections from its walls. Other examples of the formation of spurious dissepiments producing changes in the ovary have been already mentioned.

2nd. Other alterations are produced by the abortion or obliteration of parts, as the ovary ripens. The young ovary of the Oak consists of three cells, each of which contains two ovules, but the fruit has only one cell and one seed, so that in the course of development five ovules and two cells have become obliterated. In the Birch we have an ovary with two cells, containing one ovule in each, but the fruit is one-celled and one-seeded, so that here one cell and one ovule have become obliterated. In the Ash, Horse-chestnut, Elm, and many other plants, similar changes are produced by the abortion or obliteration of certain parts of the ovary.

3rd. Changes are frequently caused in the ovary from a great development of succulent parenchyma. This is associated also with changes in the contents of the cells of the parenchyma, which become charged with sugar, vegetable acids, and various flavouring matters, giving its peculiar character to each fruit. The pulp of the Guava, Gooseberry, Tomato, and some other fruits, in which the seeds are embedded, appears to be produced from the placentas; and that of the Orange is of a similar nature. The succulent parenchyma in other cases becomes dry and hard, leading to the formation of woody or papery fruits.

Although the fruit may thus be described as consisting essentially of the ovary or ovaries, modified in the directions described, other parts of the flower are also frequently present, and enter into its composition. In those cases where the receptacular tube is adherent to the ovary, as in the Apple, Quince (*fig.* 299), Pear, Melon, and Gooseberry, it necessarily forms a part of the fruit; in the Rose the concave thalamus (*fig.* 285, *r*, *r*), which bears the carpels on its inner surface, becomes a portion of the fruit; in the Strawberry (*fig.* 505) the fruit consists of the succulent hemispherical thalamus, bearing the carpels on its convex surface; in the Acorn (*fig.* 197), Hazel-nut (*fig.* 198), and Filbert, it consists of pistil and bracts, combined together.

FIG. 502.

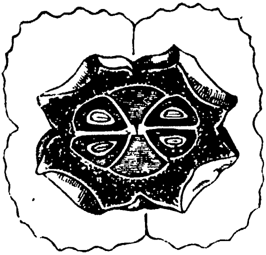


FIG. 503.

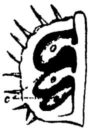


FIG. 504.

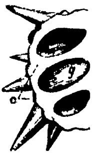


FIG. 505.

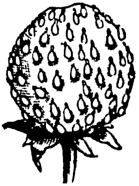


Fig. 502. Transverse section of the fruit of *Pretrea zangueba* From Lindley.——*Fig.* 503. A vertical section of a cell of the ovary of *Tribulus terrestris.* *o*, *o*, *o*. Ovules. *c*. Projections from the wall which are commencing to separate the ovules.——*Fig.* 504. A vertical section of a cell of the mature ovary or fruit of the same, in which the partitions, *c*, completely separate the seeds, *g*.——*Fig* 505. Pseudocarp of the Strawberry.

We have further a third kind of fruit, in the construction of which several flowers take part; in the Pineapple (*fig.* 167) it consists of their ovaries, floral envelopes, and bracts, all of which have coalesced and become succulent; in the Fig also (*fig.* 208) we have a fruit produced by a number of separate flowers enclosed in a hollow fleshy receptacle. These examples show, that although the fruit consists essentially of the modified ovary, yet the term is also applied to whatever is combined with the ovary so as to form a covering to the seeds. Fruits which are formed from a single flower, but not entirely from the pistil, are now commonly termed *spurious fruits* or *pseudocarps*, while those formed entirely from the pistil are called *true fruits*. Those which are formed from several flowers are known as *aggregated* or *anthocarpous fruits*.

GENERAL CHARACTERS OF THE FRUIT.—The structure of the true fruit resembling in all important particulars that of the ovary, the modifications which it presents, as to composition, position, &c., are described by similar terms. We may have *simple* or monocarpellary and *compound* or polycarpellary fruits; also *apocarpous* and *syncarpous* ones. Simple fruits, like simple ovaries, are normally *one-celled* or *unilocular*; while a polycarpellary fruit may have one or more cells, according to the absence or presence of dissepiments, and the number of cells is indicated by terms similar to those used when speaking of the compound ovary.

The fruit, like the ovary, necessarily possesses one or more placentas, to which the seeds are attached; and the same terms are used in describing the different kinds of placentation, as in the case of the ovary; these differences are usually more evident in the fruit.

The fruit, again, is described as *superior* or *inferior*, in the same sense as these terms are used in speaking of the ovary. A fruit is inferior when it is formed from an inferior ovary, as in the Melon; it is superior, as in the Mignonette (*fig.* 209) and Pea (*fig.* 512), when the ovary is superior, and the calyx non-adherent. Inferior fruits should, strictly speaking, be classed with pseudocarps, as they include parts of other structures than the pistil. They are generally, however, reckoned among true fruits.

The *base* of the fruit is that point by which it is united to the thalamus; the *apex* is indicated by the attachment of the style; hence in those ovaries where the style is lateral or basilar, as in many *Rosaceæ* (*figs.* 441 and 442), *Labiatæ* (*fig.* 412), and *Boraginaceæ* (*fig.* 413), the organic apex of the fruit will be also thus situated, so that the geometrical and organic apices will be very different.

COMPOSITION OF THE FRUIT.—The fruit when perfectly formed consists of two parts: namely, the *pericarp*, and the *seed* or *seeds* contained within it. In the majority of cases when the seeds are abortive the pericarp withers, and the fruit does not ripen. But there are many exceptions to this; the Bananas and many Oranges and Grapes produce no seeds, but the pericarp is nevertheless fully developed; and in Plantains and the Bread-fruit the pericarps develop most extensively, and become best adapted for food, when the seeds are chiefly or entirely abortive. Generally speaking, however, the development of the seeds and pericarp proceeds together after the process of fertilisation has been effected, and only then can *perfect fruit* be formed; for although in common language we apply the term fruit in those instances where no seeds are produced, yet strictly speaking such are not fully formed fruits, but only enlarged and swollen pericarps.

The Pericarp.

In some cases the pericarp clearly indicates its homology with a leaf-blade by remaining in a condition not very dissimilar to that part of a leaf folded inwards and united by its margins, as in the Bladder Senna (*fig.* 506); such a fruit is described as *foliaceous* or *leafy.*

FIG. 506.

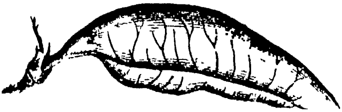


Fig 506. Foliaceous bladdery legume of the Bladder Senna (*Colutea arborescens*).

In the majority of fruits the pericarp consists simply of the modified walls of the ovary; but when the calyx or receptacle is adherent it necessarily presents a more complicated structure.

The pericarp sometimes exhibits three layers or regions (*fig.* 534): an external, called the *epicarp* or *exocarp*, *ep*; a middle, the *mesocarp*, *mt*; and an inner, the *endocarp*, *en*. If the middle layer becomes fleshy or succulent, it is then termed the *sarcocarp*; the inner layer in some fruits becomes very hard, and is then called the *stone* or *putamen.*

These layers are well seen in the Peach, Apricot, Cherry, Plum, and most other drupaceous fruits; the separable skin is the epicarp; the pulpy part, which is eaten, the mesocarp or sarcocarp; and the stone enclosing the seed, the endocarp or putamen. In the Almond, the seed is enveloped by a thin woody shell, constituting the endocarp, which is itself surrounded by a thin green layer, formed of the combined mesocarp and epicarp. In the Date the outer brownish skin is the epicarp; the thin paper-like layer enclosing the seed is the endocarp; and the intermediate pulpy part is the mesocarp or sarcocarp. In the Walnut, the woody shell enveloping the seed, which is commonly termed the nut, is the endocarp; and the green covering of this, called the husk, consists of the mesocarp and epicarp combined. In these fruits, and in others which might be quoted, the pericarp is more or less differentiated into separate layers; but in most cases no such differentiation can be observed.

In describing the structure of the carpel, we found that the ovary presents two sutures: one of which, called the ventral suture, corresponds to the line of union of the margins of the lamina of the carpellary leaf, and is consequently turned towards the axis or centre of the flower; and the other, termed the dorsal suture, corresponds to the midrib of the lamina, which is directed towards its circumference. The simple fruit being formed, in most cases, from the mature ovary, also presents two sutures, which are distinguished by similar names. These, like those of the ovary, may frequently be distinguished externally, either by a more or less projecting line, or by a slight furrow; in the Peach (*fig.* 537), Cherry, Plum, and Apricot, the ventral suture is very evident, although the dorsal suture has become nearly effaced; while in the Bladder Senna (*fig.* 506), Pea, and other fruits of the *Leguminosæ*, both dorsal and ventral sutures are clearly visible externally.

In a polycarpellary ovary with two or more cells, in which the placentation is axile, it must be evident, of course, that the dorsal sutures alone can be observed externally, as the ventral sutures of the component ovaries are turned towards and meet in the axis of the flower, and are hence removed from view; it follows also that the number of dorsal sutures corresponds to the number of carpels of which such an ovary is formed. In a fruit presenting similar characters, we find of course a similar disposition of the sutures. When an ovary, on the contrary, is formed of the blades of two or more carpellary leaves, the margins of which are not inflected, or only partially so, and is therefore one-celled, and the placentation parietal or free central, both ventral and dorsal sutures may be observed externally, alternating with each other. The fruit, which is formed in a similar manner, necessarily presents a similar alternation of the sutures on its external surface.

Dehiscence.—The pericarp in some cases opens or splits when the fruit is ripe, so as to allow the seed or seeds to escape; in other cases it remains closed, and the seeds can then only become free by its rupture or decay. In the former case the fruit is said to be *dehiscent*; in the latter, *indehiscent*. Those fruits such as the Nut, Cherry, Apricot, Plum, and Date, which have very hard or fleshy pericarps, are usually indehiscent.

Dehiscent fruits open in various ways:—

1st. By splitting *longitudinally*, either in the lines of the dorsal sutures, or at the junction of the component carpels only, or at these points as well as at the dorsal sutures. In all such cases the pieces into which the fruit separates are called *valves*, and these valves, when the fruit is normal in its structure, are either equal in number to the cells, or component carpels, or they are twice as numerous. In fruits formed of a single carpel, which open only by the ventral or dorsal suture, there will be only one valve (*figs.* 510 and 511), corresponding to the one carpel; but if the carpel opens by both sutures (*fig.* 512), there will be two valves. In fruits composed of several cells the valves will be equal in number to the component carpels, if the dehiscence takes place only by the dorsal suture (*figs.* 516 and 517), or in the line of union of the component ovaries (*figs.* 513 and 514); or they will be double the number, if the dehiscence takes place by both these parts. In polycarpellary one-celled fruits the valves will be equal in number to the component carpels, if the dehiscence occurs only by the ventral (*fig.* 522) or dorsal sutures (*fig.* 515); or double the number, if by all the sutures. When there is a distinct axis left after the separation of the valves, this is called the *columella* (*fig.* 543, *a*).

2nd. By splitting transversely, so that the upper part of the fruit separates from the lower like the lid from a jar or box.

3rd. By rupturing in an irregular manner by little *pores*.

We have thus three kinds or classes of dehiscence, which are called respectively:—1. *Valvular*; 2. *Transverse* or *Circumscissile*; and 3. *Porous*.

1. VALVULAR DEHISCENCE.—This may be either partial or complete: in *Dianthus* (*fig.* 508), *Lychnis* (*fig.* 507), and many other members of the *Caryophyllaceæ*, the dehiscence takes place only at the upper part of the fruit, which then appears toothed, the number of teeth corresponding to that of the valves in complete dehiscence. A somewhat similar mode of partial dehiscence occurs in certain Saxifrages, and in the Mignonette (*fig.* 509); in the latter plant one large orifice may be observed at the summit of the fruit at an early stage of its growth, and long before the seeds are ripe. At other times the separation of the fruit into valves is more or less complete,

so that the nature of the dehiscence is at once evident. There are various modifications of these complete forms of valvular dehiscence. In fruits which are formed of but one carpel, the dehiscence may take place by the ventral suture only, as in the Columbine (*fig.* 510) and Aconite (*fig.* 553); or by the dorsal suture only, as in some Magnolias (*fig.* 511); or by both dorsal and ventral sutures, as in the Pea (*fig.* 512), Bean, and many other members of the *Leguminosæ*. This form of dehiscence is commonly known as *sutural*.

FIG. 507.

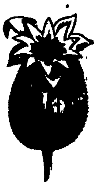


FIG. 508.

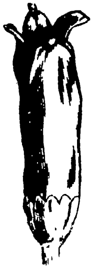


FIG. 509.

FIG. 510.

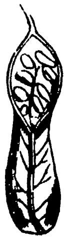


FIG. 511.

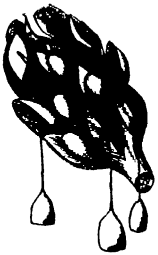


FIG. 512.

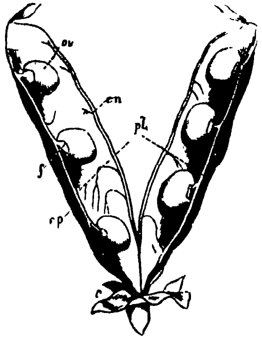


Fig. 507. Fruit of *Lychnis*.——*Fig.* 508. Fruit of *Dianthus*.——*Fig.* 509. Fruit of Mignonette (*Reseda*).——*Fig.* 510. Follicle of Columbine (*Aquilegia*), dehiscing by ventral suture.——*Fig.* 511. Follicles of *Magnolia glauca*, each dehiscing by its dorsal suture. The seeds are suspended from the fruits by long stalks or funiculi.——*Fig.* 512. Legume of the Pea, which has opened by both dorsal and ventral sutures; hence it is two-valved. *c.* Calyx. *ep.* Epicarp. *pl.* Placenta. *ov.* Seeds attached to the placenta by a funiculus or stalk, *f.* *en.* Endocarp.

In compound fruits having two or more cells, and therefore axile placentation, there are three kinds of valvular dehiscence, which are called respectively *septicidal*, *loculicidal*, and *septifragal*.

A. *Septicidal Dehiscence.*—In this the fruit is separated into its component ovaries or carpels by a division taking place between the two halves of each dissepiment (*figs.* 514 and 513). Examples may be seen in *Colchicum* and *Rhododendron*. Here each valve corresponds to a carpel, and the valves are said to have their margins turned inwards. In this dehiscence the placentas, with the seeds attached, are carried away with the valves, as in *Colchicum* (*fig.* 514).

B. *Loculicidal Dehiscence.*—This term is used when each carpel opens by its dorsal suture, or through the back of the cells, and the valves separate from the axis, carrying the dissepiments with them (*figs.* 516 and 517). Here each valve is composed of the united halves of two adjoining carpels, and the valves bear the dissepiments in the middle. Examples may be seen in the Iris (*fig.* 562) and *Hibiscus* (*fig.* 516).

FIG. 513.

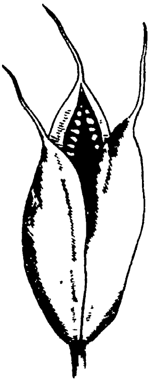


FIG. 514.

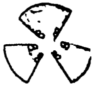


FIG. 515.

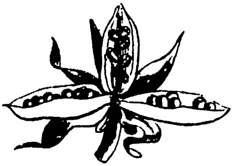


FIG. 516.

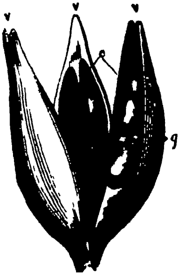


FIG. 517.

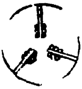


Fig. 513 Capsule of the Meadow Saffron (*Colchicum autumnale*), showing septicidal dehiscence.——*Fig.* 514. Diagram of septicidal dehiscence, showing the placentas and seeds carried away with the valves.——*Fig.* 515. One-celled fruit of Heartsease (*Viola tricolor*), dehiscing in a loculicidal manner.——*Fig.* 516. Capsule of a species of *Hibiscus*, dehiscing loculicidally. *v*, *v*, *v*. Valves. *c*. Dissepiments. *g*. Seeds.——*Fig.* 517. Diagram of loculicidal dehiscence, in which the valves carry the placentas with them.

C. *Septifragal Dehiscence.*—In this form of dehiscence the carpels open by their dorsal or ventral sutures, as in loculicidal or septicidal dehiscence, and at the same time the dissepiments rupture, so that the valves fall away, leaving the seeds attached to a central column (*figs.* 519 and 520). This form of dehiscence may be seen in *Datura Stramonium* (*fig.* 521) and *Cedrela* (*fig.* 519). The placentas bearing the seeds are here attached to the axis, *a*, between the dissepiments, *c*, *c*. Septifragal dehiscence may be combined with either the loculicidal or septicidal form (*figs.* 520 and 518).

In polycarpellary fruits with one cell having parietal or free central placentation, we have two forms of dehiscence; these correspond to the ordinary septicidal and loculicidal kinds just described. In compound fruits with parietal placentation, the dehiscence may take place through the confluent margins or sutures of the adjoining carpels, so that each placenta is divided into its two lamellæ, as in the species of Gentian (*fig.* 522). In this case the dehiscence takes the septicidal form, and each valve therefore represents one of the component carpels of the fruit. The dehiscence may, on the other hand, take place through the dorsal sutures, as in the Pansy (*fig.* 515), in which case it is loculicidal, and each valve is composed of the adjoining halves of two carpels. These forms may be readily distinguished by the varying attachment of the placentas and seeds in the two cases; in the former instance, each valve bears the placentas and seeds on its two margins (*fig.* 522); in the latter, the placenta and seeds are attached to the centre of each valve (*fig.* 515). It happens in some cases, as in the fruit

FIG. 518.

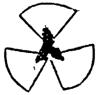


FIG. 520.

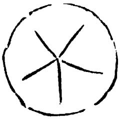


FIG. 519.

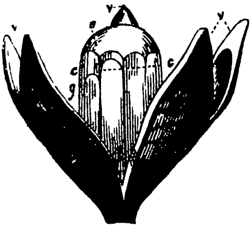


FIG. 521.

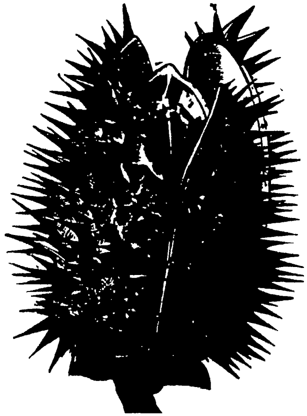


Fig. 518. Diagram of septifragal combined with septicidal dehiscence, showing the valves breaking away from a central column formed by the union of the placentas.——*Fig.* 519. Capsule of *Cedrela angustifolia*, showing septifragal dehiscence. *v*, *v*, *v*. Valves. *a*. Axis bearing the dissepiments, *c*, *c*, and seeds, *g*.——*Fig.* 520. Diagram illustrating septifragal combined with loculicidal dehiscence.——*Fig.* 521. Capsule of *Datura Stramonium*, showing septifragal dehiscence.

of the Wallflower (*fig.* 523), that the placentas bearing the seeds remain undivided, and the valves break away from them, so that they are left attached to a frame or *replum*, which is a spurious dissepiment derived from the placentas.

In polycarpellary fruits with free central placentation, the same forms of dehiscence occur as in those with parietal placentation, but here it is difficult in many cases to speak positively as to the nature of the dehiscence from the absence of seeds or dissepiments upon the valves. The plan usually adopted is to count the number of the valves and compare their position with that of the sepals or divisions of the calyx. As the different whorls of the flower in a regular arrangement alternate with one another, the component carpels of the fruit should alternate with the sepals or divisions of the calyx. Therefore if the fruit separates into as many portions as there are sepals or parts to the calyx, and if these valves are then placed alternate to them, they represent the component carpels, and the dehiscence is consequently of the septicidal type; if, on the contrary, the valves are equal and opposite to the sepals or divisions of the calyx, each valve is composed of the adjoining halves of two carpels, and the dehiscence is of the loculicidal type. Sometimes the number of valves is double that of the calycine segments or

FIG. 522.

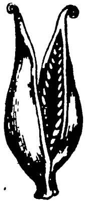


FIG. 523.

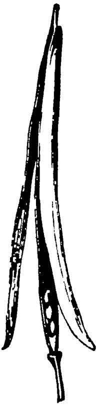


FIG. 524.

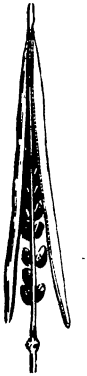


Fig. 522. One-celled fruit of a species of Gentian dehiscing in a septicidal manner.——*Fig.* 523. Fruit of siliqua of the Wallflower, showing the separation of two valves from the replum.——*Fig.* 524. Fruit of Celandine (*Chelidonium majus*), with the valves separating from the placentas.

sepals, in which case each valve is formed of half a carpel, the dehiscence of the fruit having taken place by both its dorsal and ventral sutures.

In all these varieties of valvular dehiscence, the separation may take place either from above downwards, which is by far the more usual form (*figs.* 513, 516, 519, and 521); or occasionally from below upwards, as in the Celandine (*fig.* 524), and universally in the members of the *Cruciferæ* (*fig.* 523).

In some fruits the carpels separate from each other without opening; some of these show the axis elongated, forming a columella or carpophore, as in the Mallow, and in the *Geraniaceæ* (*fig.* 526, *a*) and *Umbelliferæ* (*fig.* 540). The carpels which are united to it separate from it without their ovaries opening. The ovaries of such carpels sometimes open afterwards by their dorsal sutures (*fig.* 543, *sd*). When such carpels separate with a certain amount of elasticity from the axis to which they are attached, as in some *Euphorbiaceæ*, they have been called *cocci* (*fig.* 543, *c, c, c*). All fruits the carpels of which separate from each other without opening are called *schizocarps*; they are indehiscent fruits, as the primary splitting does not set the seeds free.

FIG. 525.

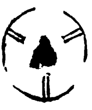


FIG. 526.

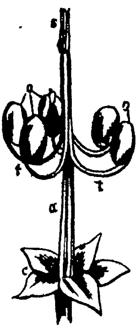


Fig. 525. Diagram of septifragal dehiscence, in which the valves have separated from the placentas, which remain as a central column with the seeds attached. *Fig.* 526. Fruit of a species of *Geranium*. *c.* Persistent calyx. *a.* Axis or carpophore from which the ovaries, *o*, *o*, with their styles, *t*, *t*, are separating. *s.* Stigmas.

In certain fruits, such as those of *Linum catharticum*, the ovaries open first by their dorsal suture, and then separate from each other septicidally.

2. TRANSVERSE OR CIRCUMSCISSILE DEHISCENCE.—In this kind of dehiscence the opening takes place by a transverse fissure through the pericarp across the sutures, so that the upper part is separated from the lower like the lid of a jar or box, as in *Hyoscyamus* (*fig.* 527) and *Anagallis* (*fig.* 560). Sometimes the dehiscence only takes place half round the fruit, as in *Jeffersonia*, in which case the lid remains attached to the pericarp on one side, as by a hinge.

In the Monkey-pot (*fig.* 528), the lower part of the ovary is adherent to the receptacular tube, and the upper portion is free; and when dehiscence takes place, it does so transversely at the part where the upper free portion joins the lower adherent one, so that it would appear as if the adherence of the calyx had some effect in this case in producing the transverse dehiscence. Such fruits are sometimes called *operculate*, a term which is also applied by other botanists to all forms of transverse dehiscence in which the upper portion of the pericarp separates from the lower in the form of a *lid* or *operculum*.

Transverse dehiscence may occur in fruits which are formed by a single ovary or carpel, as well as in the compound ones mentioned above. The lomenta of *Coronilla*, *Hedysarum* (*fig.* 529), *Ornithopus*, &c., separate in this way when ripe into as many portions as there are seeds.

3. Porous Dehiscence.—This is an irregular kind of dehiscence, in which the fruits open by little pores or slits formed in their pericarps. These openings may be situated either at the apex, side, or base of the fruit; and they are described accordingly, as *apicular*, *lateral*, or *basilar*. Examples of this kind of dehiscence are exhibited by the Poppy, in which several pores are placed beneath the peltate disc to which the stigmas are attached; and by *Antirrhinum* (*fig.* 430), where there are two or three orifices, one of which is situated near the summit of one cell of the ovary, and the rest somewhere in the other. In various species of *Campanula* (*figs.* 530, *t*, *t*, and 531), in which the ovary is inferior, and divided into several loculi, each of the latter opens externally by a single pore. The pericarp is composed by the adhesion of the receptacular tube to the wall of the ovary. The apertures are situated either at the sides (*fig.* 530, *t*, *t*) or towards the base (*fig.* 531) of the cells, and are very irregular in shape.

Fig. 527.

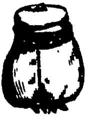


Fig. 528.

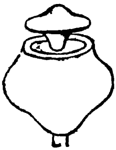


Fig. 529.

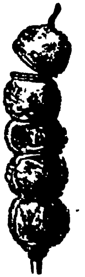


Fig. 527. Fruit of Henbane (*Hyoscyamus*) with transverse dehiscence. This fruit is termed a pyxis.——*Fig.* 528. Pyxis of the Monkey-pot (*Lecythis ollaria*).——*Fig.* 529. Lomentum of a species of *Hedysarum* separating transversely into one-seeded portions.

Kinds of Fruit.—Many kinds of fruit have been described and several classifications have been proposed for them, but there is still not very great accordance among botanists upon this subject.

We have seen that in most cases the fruit arises from changes in the carpels in consequence of fertilisation. All these forms may be described as *true fruits.* It often happens however that other parts of the flower undergo similar modifications, and a number of structures result, in which the true fruits can frequently be distinguished separately. The idea of the fruit which is associated with these forms is a rather conventional one, its leading features being succulence or palatability. Such fruits, originating, like the first group, from single flowers, we may speak of as *spurious fruits or pseudocarps.* A third form also is found, in which the 'fruit' is the result of the more or less complete cohesion of a number of flowers, various parts of which, or the axis on which they are borne, have become succulent. These may be called *aggregated* or *anthocarpous* fruits.

FIG. 530.

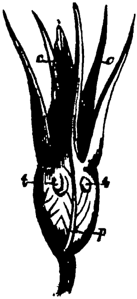


FIG. 531.

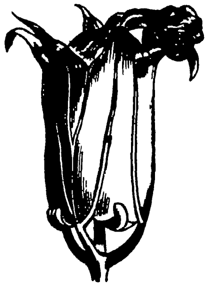


Fig. 530. Immature fruit of a species of *Campanula.* *p.* Pericarp. *t, t.* Pores at the sides. *c, c.* Receptacular tube united below to the wall of the fruit so as to form a part of the pericarp.——*Fig.* 531. Fruit of a species of *Campanula* dehiscing by pores at its base.

A. TRUE FRUITS.

Of these many varieties occur, rendering a classification necessary. As there is a possible broad distinction, based on the way they liberate their seeds, we may divide them into *Indehiscent* and *Dehiscent* fruits. Further division may be based on the number of carpels in each.

Indehiscent Monocarpellary Fruits.

1. *The Achene* is a very small superior, one-celled, one-seeded fruit, with a dry indehiscent pericarp, which is separable

from the seed, although closely applied to it. Such fruits may be mistaken for seeds, but can be distinguished from them by bearing on some point of their surface the remains of the style. This style is very evident in the Anemone (*fig.* 532). Examples may be seen also in the Clematis, and in the plants of the orders *Labiatæ* and *Boraginaceæ* (*fig.* 533). In rare cases we find a flower producing but a single achene.

2. *The Utricle* is a superior, one-celled, one- or few-seeded fruit, with a thin, membranous, loose pericarp, not adhering to the seed; generally indehiscent, but rarely opening transversely.

FIG. 532.

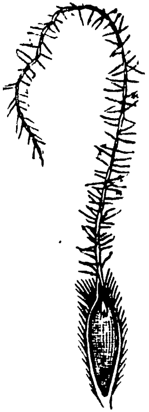


FIG. 533.

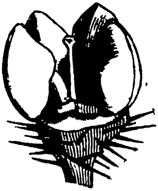


FIG. 535.

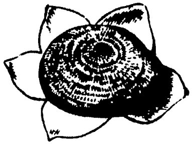


FIG. 534.

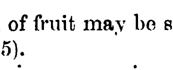


Fig. 532. Vertical section of an achene of the Pasque-flower (*Anemone Pulsatilla*). The fruit is said to be tailed in this instance in consequence of being surmounted by a feathery style.——*Fig.* 533. Achenes of Bugloss (*Lycopsis*).——*Fig.* 534. Vertical section of the drupe of the Cherry. *cp.* Epicarp. *en.* Endocarp. *mt.* Mesocarp. *g.* Seed with embryo.——*Fig.* 535. Utricular fruit of *Chenopodium*, surrounded by the persistent calyx.

Examples of this kind of fruit may be seen in *Amaranthus* and *Chenopodium* (*fig.* 535).

3. *The Caryopsis* is a superior, one-celled, one-seeded, indehiscent fruit with a thin dry membranous pericarp, completely and inseparably united with the testa or skin of the seed (*figs.* 538 and 539). It is found in plants of the order *Graminaceæ*. This form must be carefully distinguished from a seed, with which it is often confused.

4. *The Drupe.*—This is a superior, one-celled, one- or two-seeded, indehiscent fruit, having the pericarp altogether separable into three well-defined layers: namely, epicarp, mesocarp,

R 2

and endocarp. Of these the epicarp is a thin skin; the mesocarp, or *sarcocarp*, a fleshy or succulent mass; and the endocarp hard and woody. This layer is known as the *stone* or *putamen*, hence the drupe is sometimes called a *stone-fruit.* Examples are afforded by the Peach (*figs.* 536 and 537), Apricot, Plum, Cherry (*fig.* 534), and Olive. The fruit of the Almond presents all the characters of the drupe, except that the mesocarp is of a toughish texture instead of being succulent. The fruit of many Palms, such as the Date, is a drupe whose endocarp is papery and whose seed instead is hard and stony. The latter must not be confused with the endocarp of the Plum, which it resembles in texture. Many fruits, such as the Cocoa-nut, which are sometimes termed drupes, are improperly so called, as they are in reality compound, or formed originally from two or more carpels or ovaries. They present other characters differing from those of monocarpellary fruits.

FIG. 536.

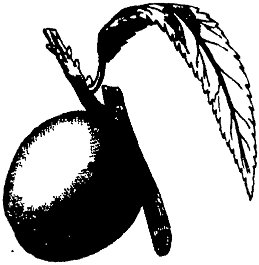


FIG. 537.

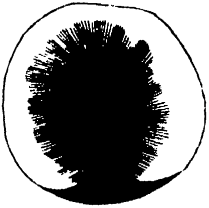


Fig. 536. Drupe of the Peach.——*Fig.* 537. The same cut vertically.

The Raspberry (*fig.* 570) and Bramble bear a number of small drupes, or *drupels*, crowded together upon a conical dry thalamus. These form an etærio of drupes.

Indehiscent Polycarpellary Fruits.

1. *The Cypsela.*—This differs from the achene by being inferior and bicarpellary. It occurs in all plants of the order *Compositæ*. When the calyx is pappose it remains attached to the fruit, as in Salsafy and Dandelion.

2. *The Glans* or *Nut* is a dry, hard, indehiscent, one-celled, one- or two-seeded fruit, produced from an ovary of two or more

cells, with one or more ovules in each cell. During development all the cells but one become obliterated, and this one contains usually a single seed, the other ovules not developing. The pericarp of the nut is not differentiated into layers, and the whole is more or less enclosed by a *cupule*. The Acorn (*fig.* 197) and the Hazel-nut (*fig.* 198) may be taken as examples. By some botanists the fruit of the Cocoa-nut Palm is called a nut, but improperly, as its pericarp presents a distinction into epicarp, mesocarp, and endocarp. Such a fruit is often described as a fibrous drupe. It is not, however, a true drupe, as it is polycarpellary.

FIG. 538.

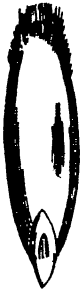


FIG. 539.

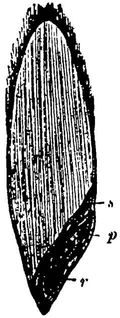


FIG. 540.

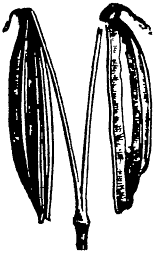


FIG. 541.

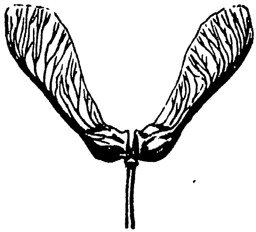


FIG. 542.

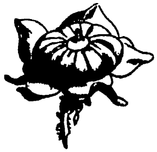


Fig. 538. Caryopsis or fruit of the Oat.—— *Fig* 539. Section of the fruit of the Oat. *p.* Plumule. *r.* Radicle. *s.* Scutellum.——*Fig.* 540. Cremocarp or fruit of *Angelica.*——*Fig.* 541. Samara or fruit of the Maple.—— *Fig.* 542. Carcerule or fruit of the Mallow (*Malva*).

3. *The Schizocarp.*—This term is applied to a number of fruits which split away from the axis into pieces corresponding to the constituent carpels. They differ from dehiscent fruits in

that the splitting does not liberate the seeds. The chief varieties are the following:—

The Cremocarp.—An inferior, dry, indehiscent, two-celled, two-seeded fruit. The two cells, or halves, of which this fruit is composed, are joined face to face to a common axis or *carpophore*, from which they separate when ripe, but to which they always remain attached by a slender cord which suspends them (*fig.* 540). Each half-fruit is termed a *mericarp*, and the inner face the *commissure*. Each portion of the fruit resembles an achene, except in being inferior; hence the name *diachænium* has been given to this fruit. Examples of the cremocarp are afforded by the plants of the order *Umbelliferæ*, but it occurs in no other order.

FIG. 543.

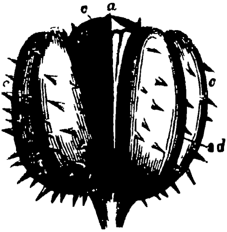


FIG. 544.

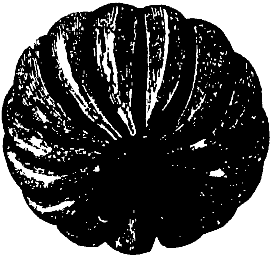


Fig. 543. Fruit of the Castor-oil plant (*Ricinus communis*), with the carpels separating from each other without opening. *c*, *c*, *c*. Carpels. *a*. Columella. *sd*. Dorsal suture where each carpel ultimately opens.——*Fig.* 544. Fruit of Sandbox-tree (*Hura crepitans*). It is composed of fifteen carpels which separate from the axis when ripe, and burst with great force

The Samara.—A superior, two- or more celled fruit, each cell being dry, indehiscent, one- or few-seeded, and having its pericarp extended into a winged expansion. Examples are afforded by the Maple (*fig.* 541), Ash, and Elm. By some botanists each winged portion of such a fruit is called a samara, and such fruits as the Maple are considered to be formed of two united samaras.

The Carcerule.—A superior, many-celled fruit, each cell being dry, indehiscent, and one- or few-seeded, and all the cells more or less cohering by their united styles to a central axis. The common Mallow (*fig.* 542) is a good example of this fruit. The central axis of the carcerule of the Geranium with its adherent styles is prolonged upwards into a large beak (*fig.* 526).

The Regma.—When the schizocarp consists of three or more carpels which separate from each other and burst with elasticity, it has been called a *regma*, and the constituent carpels are termed *cocci.* Examples are afforded by *Ricinus* (*fig.* 543) and *Hura crepitans* (*fig.* 544).

4. *The Bacca* or *Berry* is an inferior, indehiscent, one- or more celled, many-seeded, pulpy fruit (*figs.* 545 and 546). The pulp is produced from the placentas, which are axile or parietal (*fig.* 545, *pl*), and have the seeds, *s*, *s*, at first attached to them; but these ultimately become separated and lie free in the pulp, *p*.

FIG. 545.

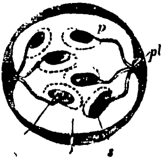


FIG. 546.

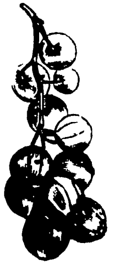


FIG. 548.

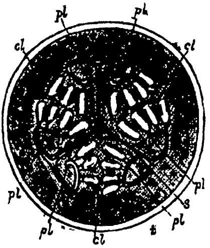


FIG. 547.

Fig. 545. Transverse section of a berry of the Gooseberry (*Ribes Grossularia*). *pl.* Placentas. *s*, *s*. Seeds embedded in pulp, *p*.——*Fig.* 546. Raceme of berries of the Red Currant (*Ribes rubrum*).——*Fig.* 547. Nuculanium or fruit of the Vine (*Vitis vinifera*).——*Fig.* 548. Transverse section of the pepo of the Melon. *cl*, *cl*, *cl*. Carpels. *pl*, *pl*, *pl*, *pl*, *pl*, *pl*. Curved placentas, sending processes, *s*, from the circumference, *t*, to the centre, and thus causing the fruit to be spuriously three-celled.

Examples are afforded by the Gooseberry and Currant. The term *baccate* or *berried* is applied by many botanists to any pulpy fruit.

5. *The Amphisarca.*—A superior, many-celled, indehiscent, many-seeded fruit, indurated or woody externally, pulpy internally. Examples, *Omphalocarpus*, *Adansonia*, *Crescentia.*

6. *The Pepo* is an inferior, one-celled or spuriously three-celled, many-seeded, fleshy or pulpy fruit (*fig.* 548). The seeds are attached to parietal placentas, and are embedded in pulp, but they never become free as is the case in the berry; hence this fruit is readily distinguished from the latter.

There has been much discussion with regard to the structure of the pepo. By some botanists the placentas are considered as axile, and the fruit normally three-celled, as it is formed of three ovaries or carpels; while by others the placentas are regarded as parietal, and the fruit normally one-celled, as defined above. Those who adopt the first view believe that each placenta sends outwards a process towards the walls of the fruit, and that these processes ultimately reach the walls and then become bent inwards and bear the seeds on the curved portions. If these processes remain, the fruit is three-celled; if, on the contrary, they become absorbed, it is only one-celled, and the placentas are spuriously parietal. According to the view here adopted, the placentas are parietal, and send processes inwards which meet in the centre, and thus render the fruit spuriously three-celled; if these are imperfectly formed or afterwards obliterated, the fruit is one-celled. This fruit is illustrated by the Melon, Gourd, Cucumber, Elaterium, and other members of the order *Cucurbitaceæ*. The fruit of the Papaw-tree resembles a pepo generally, except in being superior.

FIG. 549.

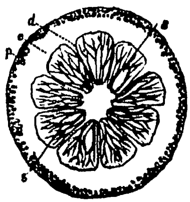


FIG. 550.

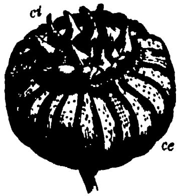


Fig. 549. Transverse section of the fruit of the Orange (*Citrus Aurantium*). *p.* Epicarp. *e.* Mesocarp. *d.* Endocarp. *s*, *s*. Seeds.——*Fig.* 550. Abnormal development of the fruit of the Orange, in which the carpels, *ce* and *ct*, are more or less distinct instead of being united.

7. *The Nuculanium.*—This fruit, of which the Grape (*fig.* 547) may be taken as an example, differs from the berry only in being superior. It is frequently called a berry.

8. *The Hesperidium* is a superior, many-celled, few-seeded, indehiscent fruit, consisting of a separable pericarp, formed of the epicarp and mesocarp combined together (*fig.* 549, *p*, *e*), and having an endocarp, *d*, which projects internally in the form of membranous partitions; these divide the pulp into a number of portions or cells, which are easily separated from each other. This pulp, as already noticed, is a development of succulent parenchyma either from the general inner lining of the ovary, or from the placentas only. The seeds, *s*, *s*, are embedded in the

pulp, and attached to the inner angle of each of the portions into which the fruit is divided. The fruits of the Orange, Lemon, and Shaddock are examples of the hesperidium. It is by no means uncommon to find the carpels of this fruit in a more or less separated state (*fig.* 550), and we have then produced what are called 'horned oranges,' 'fingered citrons,' &c., and the fruit becomes somewhat apocarpous instead of entirely syncarpous.

9. *The Tryma* is a superior, one-celled, one-seeded, indehiscent fruit, having a separable fleshy or leathery rind, consisting of epicarp and mesocarp, and a hard two-valved endocarp, from the inner lining of which spurious dissepiments extend so as to divide the seed into deep lobes. It differs but little from the ordinary drupe, except in being formed from an originally compound ovary. The Walnut affords an example.

FIG. 551.

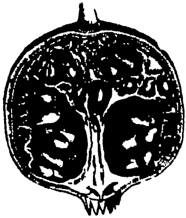


Fig. 551.—Vertical section of the balausta or fruit of the Pomegranate.

10. *The Balausta* is an inferior, many-celled, many-seeded, indehiscent fruit, with a tough pericarp. It is formed of two rows of carpels, one row being placed above the other, and surrounded by the calyx; the seeds are attached irregularly to the walls or centre. The Pomegranate fruit is the only example (*fig.* 551).

Dehiscent Monocarpellary Fruits.

1. *The Follicle.*—This is a superior, one-celled, one or many-seeded fruit, dehiscing by one suture only, which is commonly the ventral; it is consequently one-valved (*fig.* 510). By the latter character it is known at once from the legume, which opens by two sutures, and is two-valved; in other respects the two fruits are alike.

The follicles of *Magnolia glauca* (*fig.* 511) and some other species of *Magnolia* open by the dorsal suture instead of the ventral. Examples of the follicle are afforded by the Columbine (*fig.* 552), Hellebore, Larkspur, and Aconite (*fig.* 553). Each of these plants bears a whorl of three follicles, arranged on the top of the thalamus, and almost touching each other; each flower of *Asclepias*, *Vinca*, and *Pæonia* (*fig.* 554) generally forms two follicles; while the follicles of *Liriodendron* and *Magnolia* (*fig.* 511) are numerous, and arranged in a spiral manner on a more or less elongated thalamus. It rarely happens that a flower produces but a single follicle; this, however, sometimes occurs in the case of the Pæony. The two follicles of *Asclepias* are more or less united at their bases, and the seeds, instead of remaining attached to the ventral suture, as is the case in the true follicle, lie loose in the cavity of the fruit. This double fruit has therefore by some botanists been given the distinctive name of *Conceptaculum*.

2. *The Legume or Pod.*—This is a superior, one-celled, one- or many-seeded fruit, dehiscing by both ventral and dorsal sutures so as to form two valves, and bearing its seed or seeds on the ventral suture. Examples are afforded by the Pea (*fig.* 512), Bean, Clover, and most plants of the order *Leguminosæ*, which has derived its name from this circumstance.

FIG. 552.

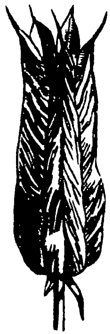


FIG. 553.

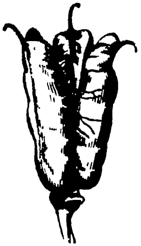


FIG. 554.

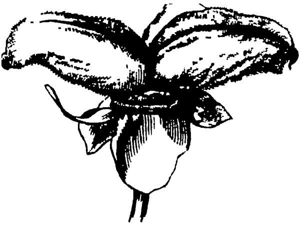


Fig. 552. Follicles of the Columbine (*Aquilegia*).——*Fig.* 553. Follicles of the Aconite (*Aconitum*).——*Fig.* 554. Follicles of the Pæony (*Pæonia*).

The legume is generally more or less convex on its two surfaces and nearly straight; but it frequently assumes curious shapes. That of some species of *Medicago* becomes spirally twisted so as to resemble a screw (*fig.* 557); those of *Scorpiurus sulcatus* and of some other *Medicagos* are coiled upon their long axis after the manner of a snail-shell (*fig.* 555); that of *Cæsalpinia coriaria* is curved like a worm. A number of other irregular forms occur. Some plants exhibit certain deviations from the ordinary structure of a legume; *Astragalus* (*fig.* 422) and *Phaca* (*fig.* 423) have one which is two-celled, in consequence of the formation of a spurious dissepiment, proceeding in the former plant from the dorsal and in the latter from the ventral suture. In other cases a number of spurious horizontal dissepiments are formed, by which the legume becomes divided into as many cells as there are seeds; *Cassia fistula* (*fig.* 417) affords an instance of this and of another irregularity, the legume being indehiscent, though the two sutures are clearly marked externally.

Other indehiscent legumes are borne by *Arachis* and *Pterocarpus*, in which there is sometimes no evident mark of the sutures externally; such legumes, however, frequently split into two valves like those of a pea, when a little pressure is applied as in the ordinary process of shelling peas.

3. *The Lomentum.*—This is a kind of legume which is constricted in a moniliform manner between the seeds. *Hedysarum* (*fig.* 529), *Ornithopus*, and *Acacia Sophora* (*fig.* 558) afford examples. It is sometimes called a *lomentaceous legume.* This fruit, together with the legume, characterises the plants of the order *Leguminosæ.* When the lomentum is ripe, it commonly separates into as many pieces as there are constrictions on its surface (*fig.* 529), but it may remain entire (*fig.* 558); in the latter case the seeds are separately enclosed in cavities which are formed by the production of as many internal spurious dissepiments as there are external constrictions.

FIG. 555.

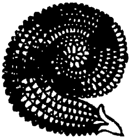


FIG. 556.

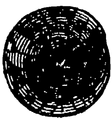


FIG. 557.

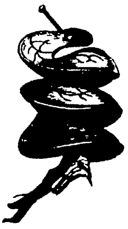


FIG. 558.

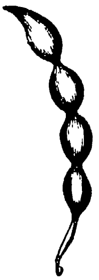


Fig. 555. Coiled-up legume of *Scorpiurus sulcata.*——*Fig.* 556. Snail-like legume of *Medicago orbiculata.*——*Fig.* 557. Spiral or screw-like legume of Lucerne (*Medicago*).——*Fig.* 558. Lomentum of a species of *Acacia.*

Dehiscent Polycarpellary Fruits.

1. *The Capsule* is a superior, one- or more celled, many-seeded dry, dehiscent fruit.

The dehiscence may take place either by valves (*Colchicum*, *fig.* 513, and *Datura*, *fig.* 521), or by pores (*Papaver*, and *Antirrhinum*, *fig.* 429); or *transversely* (Pimpernel, *fig.* 560, and Henbane, *fig.* 527); or only *partially* (Mignonette, *fig.* 509, *Dianthus*, *fig.* 508, and *Lychnis*, *fig.* 507). When the capsule dehisces transversely the fruit has received the distinctive name of *Pyxis*. The capsule is either one-celled (Mignonette, *fig.* 509, Pansy, *fig.* 515, and Gentian, *fig.* 522); or two-celled (*Scrophularia*, *fig.* 561); or three- or more celled (*Colchicum*, *fig.* 513, and *Datura*, *fig.* 521). *Helicteres* (*fig.* 559) shows a very remarkable and aberrant form, being composed of five carpels twisted spirally together. The capsule is a very common fruit, and is found almost universally in many Natural Orders, as *Papaveraceæ*, *Carophyllaceæ*, *Primulaceæ*, *Scrophulariaceæ*, *Gentianaceæ*, &c.

When a fruit resembles the ordinary capsule in every respect, except that it is inferior, it has received the name of *Diplotegia*.

FIG. 559.

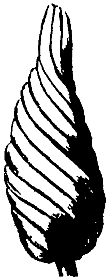


FIG. 560.

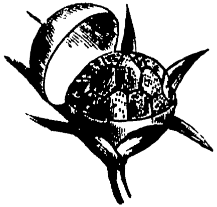


FIG. 561.

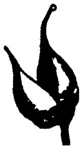


Fig. 559. Spiral capsule of a species of *Helicteres*.——*Fig.* 560. Pyxis of Pimpernel (*Anagallis*).——*Fig.* 561. Capsule of a species of *Scrophularia*, dehiscing septicidally.

2. *The Siliqua* is a superior, spuriously two-celled, many-seeded, long, narrow fruit, dehiscing by two valves which separate from below upwards, and leave the seeds attached to two parietal placentas; these are commonly connected together by a spurious vertical dissepiment, called a *replum* (*fig.* 563). The placentas are here opposite to the lobes of the stigma, instead of alternate with them, as is usually the case. Examples of this fruit are afforded by the Wallflower (*fig.* 563), Stock, Cabbage, and a large number of other members of the order *Cruciferæ*.

The siliqua is sometimes constricted in the spaces between the seeds, like the lomentum, in which case it is indehiscent; it is then called a *lomentaceous siliqua*. *Raphanus sativus* has a siliqua of this description.

3. *The Silicula*.—This fruit resembles the siliqua very closely, but it usually contains fewer seeds. The *siliqua* may

be described as long and narrow, the *silicula* as broad and short. Examples occur in the Shepherd's Purse (*fig.* 564) and Scurvy-grass.

The silicula and siliqua are the characteristic forms of fruit in the Natural Order *Cruciferæ.*

4. *The Diplotegia.*—This is the only kind of inferior fruit which presents a dry dehiscent pericarp. It has already been stated, under the head of Capsule, that the diplotegia differs from the latter only in being inferior. The species of *Iris* (*fig.* 562) and *Campanula* (*figs.* 530 and 531) afford examples of this fruit.

FIG. 562.

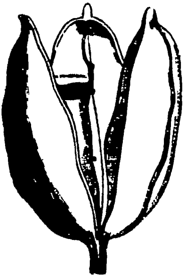


FIG. 563.

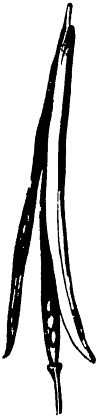


FIG. 564.

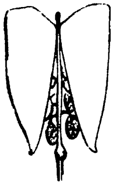


Fig. 562. Inferior capsular fruit (*diplotegia*) of the Iris, opening in a loculicidal manner.——*Fig.* 563. Fruit or siliqua of the Wallflower, showing the separation of the two valves from the replum.——*Fig.* 564. Silicula of Shepherd's Purse (*Capsella*).

The diplotegia may open either by pores (*fig.* 530), or valves (*fig.* 562), or transversely, like the ordinary capsule. In the latter case, as with the true capsule with transverse dehiscence, the fruit is called a *Pyxis.*

5. *The Cone.*—As we have seen, the pistillate flower of the *Coniferæ* has the form of an axis bearing a number of leaves arranged spirally along it, each being regarded as an open carpel with two ovules on its upper surface. When it becomes old the carpels are hard and woody, and each bears two naked seeds (*fig.* 475). Each cone is then a single fruit. Examples are afforded by the Scotch Fir (*fig.* 565), the Larch, the Hemlock Spruce (*fig.* 275), and a great many other plants of the same Natural Order. The dehiscence is brought about by the carpel-

lary scales separating from the axis for a great part of their length, so that the seeds fall from between them.

6. *The Galbulus.*—This fruit is but a modification of the Cone, differing in being more or less rounded in form instead of somewhat conical, and in having the heads of the scales much enlarged and peltate in form, with the seeds on their under surface. It is borne by the Cypress (*fig.* 567) and the Juniper (*fig.* 566). In the latter the scales become fleshy, and are united together into one mass, so that at first sight it somewhat resembles a berry; but its nature is at once seen by examining the apex, when three radiating lines will be observed, corresponding to the three fleshy scales of which the fruit is formed, and which are here but imperfectly united.

FIG. 565.

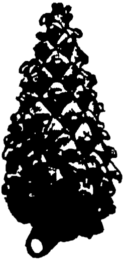


FIG. 566.

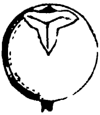


FIG. 567.

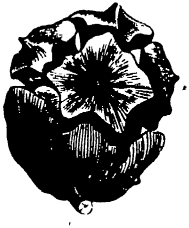


FIG. 568.

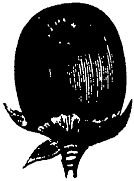


Fig 565 Cone or fruit of the Scotch Fir. —*Fig.* 566. Galbulus or fruit of the Juniper (*Juniperus communis*).— *Fig.* 567. Galbulus or fruit of the Cypress (*Cupressus sempervirens*).— *Fig.* 568. Seed of the Yew (*Taxus baccata*), surrounded by a fleshy aril

The so-called fruit of the Yew (*Taxus baccata*) (*fig.* 568) is in reality not a fruit at all; it consists of a naked seed surrounded, except at the apex, by a fleshy cup which is an aril.

B. SPURIOUS FRUITS.

1. *The Etærio.*—There are several varieties of this form. In all of them the bulk of the fruit is composed of an enlarged receptacle or thalamus on which the carpels are seated. The true fruits of *Ranunculus*, which are achenes. are placed on a dry convex receptacle which is not much enlarged; the receptacle of the Strawberry is enlarged, convex, succulent, and brightly coloured; those of *Potentilla* and some other members of the order *Rosaceæ* are enlarged but not succulent.

In the fruit of the Rose the achænia, instead of being placed upon an elevated thalamus, as in the ordinary etærio, are situated upon a concave thalamus, to which the calyx is attached (*fig.* 285, *r*, *r*). This modification of the ordinary etærio has been considered by some botanists a separate fruit, and they have given it the name of *Cynarrhodon.* A similar kind of fruit also occurs in *Calycanthus.*

2. *The Pome* is an inferior, indehiscent, two- or more celled, few-seeded, fleshy fruit, the carpels of which are surrounded by a fleshy mass, consisting of the succulent concave thalamus, in which they are embedded. The pome thus resembles the cynarrhodon, except that the carpels and the thalamus are fused together. The carpels themselves are fleshy or bony. In the former case each has a differentiated endocarp which is cartilaginous in character; in the cavity of each carpel is a single seed. Examples may be seen in the Apple (*fig.* 571), Pear, Quince (*fig.* 299), Medlar, and Hawthorn.

FIG. 569.

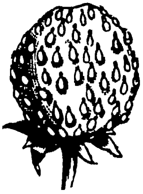


FIG. 570.

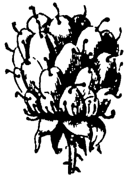


FIG. 571.

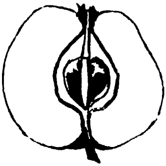


Fig. 569. Etærio of the Strawberry, consisting of a swollen succulent receptacle on which are a number of achenes.——*Fig.* 570. Etærio of the Raspberry.——*Fig.* 571. Vertical section of the pome or fruit of the Apple (*Pyrus Malus*).

C. ANTHOCARPOUS OR AGGREGATED FRUITS.

The fruits so far described are derived from single flowers. Those treated of under this section are the result of the fusion of several flowers together, whose carpels, floral envelopes, and bracts all become coherent into a single mass. The latter may be either woody or succulent. An anthocarpous fruit is thus the product of an inflorescence and not of a single flower.

1. *The Sorosis.*—In the construction of this fruit we find a number of separate flowers become coherent with the axis from which they spring. The whole mass becomes in some cases succulent, in others woody. The first case is represented

by the Pineapple (*fig.* 574); each polygonal area marked upon its exterior represents a flower. The Mulberry (*fig.* 572) affords another instance, the succulent part being mainly the calyces of the constituent flowers. A comparison of the Mulberry may be made with the Raspberry (*fig.* 573). The former is a polythalamic or aggregated fruit, the latter a monothalamic one. The succulent portion of the Mulberry is derived from the calyces of a group of flowers, that of the Raspberry from the drupelets of a single one. The two fruits, though constituted on such different plans, yet present a certain superficial resemblance. The fruit of the Plane tree is constructed in a similar manner, but the very numerous flowers and their axis all become woody. The resulting fruit is globular in form.

FIG. 572.

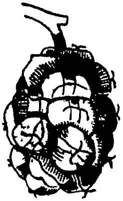


FIG. 573.

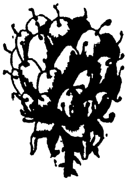


FIG. 574.

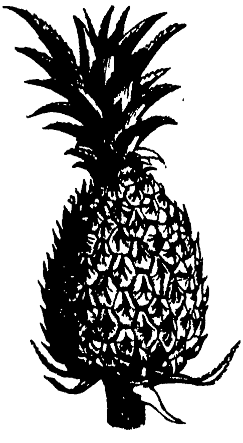


Fig. 572. Sorosis or fruit of the Mulberry (*Morus nigra*).——*Fig.* 573. Fruit (*etærio*) of the Raspberry (*Rubus Idæus*).——*Fig.* 574. Pineapple fruit (*Sorosis*), surmounted by a crown of empty bracts.

2. *The Syconus.*—This is an anthocarpous fruit, formed of an enlarged and more or less succulent receptacle which bears a number of separate flowers. The Fig (*fig.* 575) is an example of a syconus. In this the flowers are almost entirely enclosed by the enlarged hollow pear-shaped receptacle, and what are commonly called seeds are in reality one-seeded fruits resembling achænia. *Dorstenia* (*fig.* 576) supplies another example of the syconus, although it differs a good deal from that of the

Fig in its general appearance; the receptacle is less succulent, and only slightly concave except at its margins, so that the separate fruits are here readily observed.

The Seed.

We have seen that the seed is a structure which is peculiar to the group of Phanerogams or flowering plants, and have discussed the causes which lead to its formation. There are several morphological features of importance connected with it which still remain for us to consider. As the seed is the body produced from the ovule in consequence of fertilisation, we see that its structure must be comparable with that of the latter.

FIG. 575.

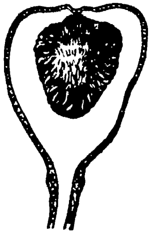


FIG. 576.

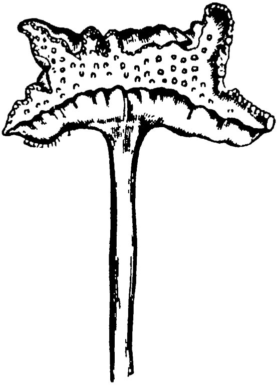


Fig 575. Syconus of the Fig (*Ficus Carica*), showing pear-shaped fleshy receptacle bearing achenes on its inner surface.—*Fig.* 576. Syconus of a species of *Dorstenia*.

It is, however, much more complex because it contains the whole of the gametophyte of the plant, together with the new sporophyte to which the latter gives origin. The latter is the body commonly called the embryo. We may have thus three distinct generations represented in the seed. 1. The megaspore and the remains of the original megasporangium, or the nucellus of the ovule with its integuments. The latter are frequently the only part of the sporangium remaining, the nucellus itself having disappeared. 2. The gametophyte, consisting of a mass of tissue of variable dimensions developed inside the spore or embryo-sac. In the Angiosperms another mass of tissue is formed after the fertilisation of the oosphere. This was till recently held to be part of the gametophyte, but its real morphological nature is now uncertain. This again is frequently very much reduced in dimensions, or it may be altogether absent, having been partially or entirely absorbed by the embryo. 3. The new sporophyte, or embryo, which may be small and embedded in the endosperm, or may be large, filling the embryo-sac, having absorbed the gametophyte and the endosperm during its development. If the nucellus also has been absorbed during the growth of the embryo-sac, the seed may present to view only the embryo enveloped in the modified original integuments of the megasporangium or ovule.

The terms *orthotropous*, *campylotropous*, *anatropous*, &c., are applied to seeds in the same sense as to ovules.

Structure of the Seed.—1. The Integuments or Coats.—There are usually two seed-coats or integuments, known respectively as the *testa* and the *tegmen*. In some cases a third is found, not so closely attached as the others to the body of the seed. This is known as an *arillus*. It may spring from either the funicle or the hilum.

Fig. 577.

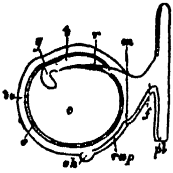


Fig. 577. The seed of a Pea with its integuments removed on one side. *pl.* Placenta. *f.* Funiculus. *rap.* Raphe. *ch.* Chalaza. *m.* Micropyle. *te.* Testa or episperm. *e.* Endopleura or tegmen. The part within the endopleura is commonly called the nucleus of the seed, and is formed of cotyledons, *c*; gemmule or plumule, *g*; radicle, *r*; and stalk or tigellum, *t*, between the plumule and radicle.

a. *Testa*, *Episperm*, or *Outer Coat* (*fig.* 577, *te*).—This integument is formed from the primine of the ovule; that of some seeds, *e.g.* those of *Acanthodium*, has in addition a coating of hair-like cells which are pressed closely to the surface of the seed by a layer of mucilage; if such seeds be moistened with water, the mucilage which confines them becomes dissolved and the hairs are set free, and then branch out in every direction.

Colour, Texture, and Surface of the Testa.—In colour the testa is generally brown, but it frequently assumes other colours; it may be uniform in tint, or variously mottled.

The testa also varies in texture, being soft or fleshy and succulent, or more or less spongy, or membranous or coriaceous, or it may become woody and hard.

Its surface is generally smooth, but is often furnished with different appendages, many of which are characteristic. It may be wrinkled (*Nigella*), striated (*Nicotiana*), marked with ridges and furrows (*Delphinium*, *fig.* 579), netted (*Nasturtium*, *fig.* 578), alveolate or pitted (*Papaver*), tuberculated (*Stellaria media*, *fig.* 580), or spiny (*Morus*). The testa of some seeds bears numerous hairs; those of the various species of *Gossypium* cover the entire surface, where they constitute the material of so much value called Cotton; those of the Willow, *Asclepias* (*fig.* 582), and *Epilobium* (*fig.* 587), are confined to certain points of the surface. In the latter cases the tufts of hairs, thus confined to certain points of the testa, constitute what is called a *coma*, and the seed is said to be *comose*.

Other seeds, particularly those of the Sandwort (*fig.* 581), and of *Catalpa*, *Bignonia*, *Swietenia*, *Moringa*, &c., have winged appendages of various kinds. These winged seeds must be carefully distinguished from samaroid fruits, such as the Ash, Elm, and Maple (*fig.* 541), where the wing is an expansion of the pericarp and not of the testa. Hairy seeds should not be confounded with pappose fruits, such as those of the *Compositæ*, *Dipsaceæ* (*fig.* 294), and *Valerianaceæ* (*fig.* 293), where the hairy-processes belong to the calyx.

FIG. 578.

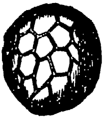


FIG. 579.

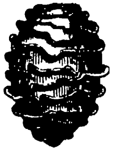


FIG. 580.

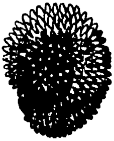


Fig. 578. Rounded seed of the Watercress (*Nasturtium officinale*). The testa is reticulated or netted.—*Fig.* 579. Obovoid seed of the Larkspur (*Delphinium*), the testa of which is marked with ridges and furrows.—*Fig.* 580. Seed of Chickweed (*Stellaria*), the testa of which is tuberculated.

Beneath the testa, in anatropous seeds (*figs.* 583, R, and 577, *rap*), and the modification of these termed amphitropous, we find the *raphe* or vascular cord connecting the hilum with the chalaza. Its situation is frequently indicated by a projecting ridge on the surface of the seed, as in that of the Orange, while at other times it lies in a furrow formed in the substance of the testa, so that the surface of the seed is smooth, and no external evidence is afforded of its position.

The testa is also usually marked externally by a scar indicating the hilum, or point by which it was attached to the funiculus or placenta. The micropyle of the Pea, as already noticed, may be sometimes seen on the surface of the testa (*fig.* 577, *m*); in those cases where no micropyle can be detected externally, its position can only be ascertained by dissection, when it will be indicated by the termination of the radicle, this being directed towards it. In some seeds, as those of *Asparagus*, the situation of the micropyle is marked by a small hardened point, which separates like a little lid at the period of germination: this has been termed the *embryotegia*.

On removing the testa the raphe can frequently be seen ramifying over the inner coat, and terminating at the chalaza (*figs.* 583, *ch*, and 577, *ch*). The structure and general appearances of these different parts have been already described.

b. *Tegmen, Endopleura, or Internal Coat* (*fig.* 577, *e*).—The inner membrane or coat of the seed is sometimes apparently wanting, probably from its complete adherence to the testa.

FIG. 581.

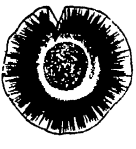


FIG. 582.

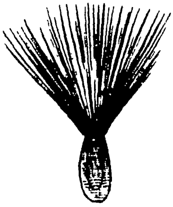


FIG. 583.

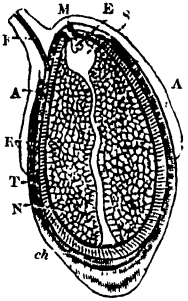


Fig. 581. Marginate or bordered seed of Sandwort (*Arenaria*).—*Fig.* 582. Comose oval seed of *Asclepias*. —*Fig.* 583. Young anatropous seed of the White Water-lily (*Nymphæa alba*) cut vertically. F. Funiculus. A, A. Gelatinous aril. T. Integuments of the seed. N. Nucellus. R. Raphe. *ch.* Chalaza. M. Micropyle. S. Embryo-sac. E. Rudimentary embryo.

When clearly distinguishable it is generally of a soft and delicate nature, of a whitish colour, and more or less transparent. It is closely applied to the kernel of the seed, which it accompanies in all its foldings and windings; in some cases it even dips down into the latter, and thus divides it more or less completely into a number of parts. Examples are afforded by the Nutmeg and Betel-nut (*fig.* 589, *p*).

Arillus.—A third covering, known as the *arillus* or *aril*, is occasionally developed. It is always found more loosely arranged than the true integuments, and generally extends only partially over them (*fig.* 583 A, A); that of the Yew forms an open cup. It grows from the base of the ovule, arising subsequently to the accomplishment of the process of fertilisation.

It is not infrequent to find outgrowths from various parts of the testa which may be confused with the aril. Such an outgrowth, arising from the region of the micropyle and spreading backwards to some distance over the testa, sometimes indeed covering the seed, has been called a *false aril* or *arillode.* An instance of it is afforded by the Spindle-tree (*fig.* 584). The Nutmeg has a similar outgrowth which is generally described as an aril; it originates, however, from both the hilum and the micropyle. It forms a scarlet covering to the seed, and is known in commerce under the name of *mace.*

Protuberances of an irregular character are often developed from other parts of the testa. They are known as *Caruncules* or *Strophioles.* They are always developed, like the arillus and arillode, subsequently to fertilisation, and are accordingly not found on the ovule. The Milkwort (*fig.* 585) bears such outgrowths at the base or hilum of the seed; the Asarabacca (*fig.* 586) and Violet have them on the side, in a line with the raphe; while those of the Spurge are placed at the micropyle. Some writers consider these caruncules as forms of the aril, of which they then distinguish four varieties, namely:—1. The *true arillus* (*Nymphæa, fig.* 583, A, A); 2. The *arillode* or *micropylar arillus* (*Euonymus, fig.* 584); 3. The *raphian arillus* (*Asarum, fig.* 586); and 4. The *chalazal arillus* (*Epilobium, fig.* 587, where the tuft of hairs at one end of the seed is regarded as an aril). Other writers again partially adopt these views, and define the caruncules as little protuberances growing from the raphe, and therefore originating independently of the funiculus or micropyle. According to this view the caruncule of the Milkwort would be regarded as a true aril, and that of the Spurge as an arillode, while the appendages

FIG. 584.

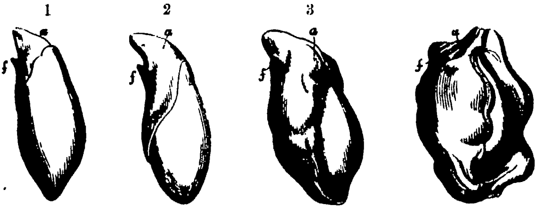


Fig 584. Progressive development of the arillode in the seed of the Spindle-tree (*Euonymus*). *a.* Arillode. *f* Funiculus. 1 represents the youngest seed; 2 and 3, the progressive development of the arillode; 4, the oldest and fully developed seed.

of Asarabacca and Violet would be true caruncules. Other botanists again, instead of using the two terms strophioles and caruncules as synonymous with each other, apply the former term only to the outgrowths proceeding from the hilum, and the latter to those coming from the micropyle.

2. THE KERNEL.—We have seen that the substance of the seed is morphologically very complex in its nature. We may or may not have the substance of the nucellus or part of it remaining. Generally this is all absorbed during the growth of the megaspore. In the seed, when present, it has received the name of the *perisperm*. We have next the embryo-sac or megaspore. In this there may be a solid mass of tissue, known as the *endosperm*, which in the Gymnosperms is the gametophyte. In the Angiosperms it is a mass of tissue developed after the fertilisation of the oosphere. Embedded in the endosperm is the body produced by the development of the fertilised oosphere, which is called the *embryo*. In other cases the embryo, by absorbing the nourishment contained in the endosperm, obliterates the latter and comes to occupy the whole interior of the embryo-sac. Then the kernel of the seed consists of the embryo or young sporophyte, which in rare cases is surrounded by a layer of perisperm, but is generally only covered by the integuments.

FIG. 585.

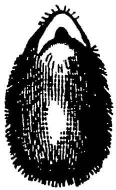


FIG. 586.

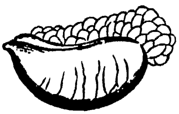


FIG. 587.

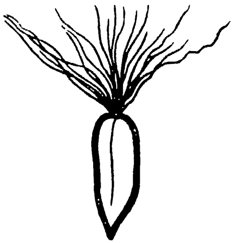


Fig. 585. Ovoid seed of Milkwort (*Polygala*), with a caruncule at its base or hilum.——*Fig.* 586. Seed of Asarabacca (*Asarum*), with a caruncule on the side, which is called by some a raphian arillus.——*Fig.* 587. Section of the comose seed of *Epilobium*. The tuft of hairy processes is sometimes called a chalazal arillus.

To the tissue which thus sometimes remains and forms a solid mass round the embryo, the name of *albumen* has been commonly applied; but it is preferably designated as the *perisperm* or *endosperm*, according to its origin as described above.

Both *endosperm* and *perisperm* may be seen in the seeds of *Nymphæa* (*figs*. 583 and 588).

From the above considerations it will be evident that the kernel of the seed may consist either of the embryo alone, as in the Bean and Pea (*fig*. 577); or of the embryo enclosed in endosperm, as in the seeds of the Poppy (*fig*. 601), Pansy (*fig*. 600, *al*), Oat (*fig*. 591), or in both endosperm and perisperm, as in those of *Nymphæa* (*fig*. 588). We have therefore two constituents of the kernel: namely, the embryo and the albumen, the latter being composed of endosperm or perisperm, or both.

a. *Albumen, Endosperm, Perisperm.*—Those seeds which have the embryo surrounded by albumen, that is, by either endosperm or perisperm, or both, are said to be *albuminous*; while those from which it is absent are *exalbuminous*. The amount of albumen will in all cases, as described above, be necessarily in inverse proportion to the size of the embryo.

The cells of the albumen contain various substances, such as starch, albuminoids, oily matter, &c., and thus act as reservoirs of nutriment for the use of the embryo during the process of germination. The varying contents of the cells, together with certain differences in the consistence of their walls, cause the albumen to assume different appearances when the seed is ripe, and thus frequently to afford good characteristic marks of different seeds. The albumen is described as *mealy*, or *farinaceous*, when its cells are filled with starch-granules, as in the Oat and other Cereal grains; it is said to be *fleshy*, as in the seeds of the Barberry and Pansy, when its walls are soft and thick; when its cells contain oil globules, as in those of the Poppy and Cocoa-nut, it is *oily*; when the cells are soft, and their walls chiefly formed of mucilage, as in those of the Mallow, it is *mucilaginous*; and when the cell-walls become very thick and hard, as in the seeds of the Vegetable Ivory Palm and the Coffee plant, the albumen is described as *horny*.

FIG. 588.

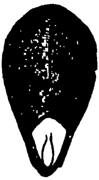


Fig. 588. Vertical section of the seed of the White Water-lily, showing the embryo enclosed in the remains of the embryo-sac, and on the outside of this the perisperm surrounded by the integuments.

Generally speaking, the albumen presents a uniform appearance throughout, as in the seeds of the Vegetable Ivory Palm; but at other times it is more or less separated into distinct compartments by the folding inwards of the tegmen, as already described. In the latter case the albumen is said to be *ruminated*, as in the seeds of the Betel-nut (*fig.* 589, *p*).

b. *The Embryo* is the rudimentary plant; it is developed from the *fertilised oosphere* in the embryo-sac. The embryo being the rudimentary sporophyte, it is necessarily the most important part of the seed, and it contains within itself, in an undeveloped state, all the members of which the plant is ultimately composed. We can distinguish in it three parts: namely, a *radicle*, a *plumule*, and one or more *cotyledons*. These parts may be readily recognised in many seeds; in the embryo of the Lime (*fig.* 590), the lower portion, *r*, is the radicle, from which the root is developed; the two expanded lobed bodies above, *c*, *c*, are the cotyledons, and between these the plumule is placed. In the Pea (*fig.* 16), the two fleshy lobes, *c*, *c*, are the cotyledons, between which there is situated a little axis, *t* (*tigellum*), the upper part or bud-like portion of which is the plumule, *n*, and the lower part, *r*, the radicle.

The great group of the Angiospermous flowering plants is subdivided into two smaller ones; in the first of these, known as the *Dicotyledons*, the embryo has two cotyledons; in the other, called the *Monocotyledons*, it has typically only one (*figs.* 591 and 593, *c*). In some exceptional cases, however, the embryo of a plant classed among the Monocotyledons has more than one cotyledon; the second cotyledon then alternates with the first instead of being opposite to it, as is invariably the case with the two cotyledons of dicotyledonous plants. The phyllotaxis of the Monocotyledons, as exhibited in the embryo, is thus always alternate, while that of the Dicotyledons is opposite. In the Gymnosperms there are often several cotyledons, so that the embryo is described as *polycotyledonous*.

(a) *The Monocotyledonous Embryo*.—The parts of the monocotyledonous embryo are in general by no means so apparent as those of the dicotyledonous. The embryo usually appears to be a solid undivided body of a cylindrical or somewhat club-shaped form, as in the seed of *Triglochin* (*fig.* 593), having a little chink, *f*, on one side near the base. If a vertical section be made parallel to this slit, a small conical projection, the *plumule*, will be noticed; by making a horizontal section, the cotyledon can be seen to be folded round the plumule, which is thus almost entirely removed from view. There is noticeable a little slit corresponding to the union of the margins of the cotyledon; this slit becomes an external indication of the presence of the plumule. The position of the cotyledon thus rolled round the plumule is similar to that of the sheaths of the leaves in most monocotyledonous plants, which, in a similar manner, enclose the young growing parts of the stem.

In other monocotyledonous embryos the different parts are more easily seen. The cotyledon of many Grasses, as, for instance, the Oat (*fig.* 591), only partially encloses the plumule, *p*, and radicle, *r*; and these parts may therefore be readily observed in a hollow space on its surface.

FIG. 589.

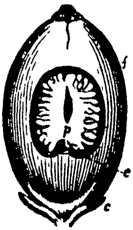


FIG. 590.

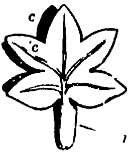


FIG. 591.

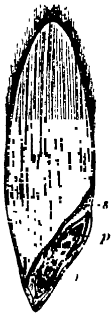


FIG. 592.

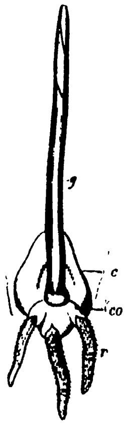


FIG. 593.

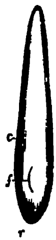


Fig. 589. Vertical section of the fruit of the Betel-nut Palm (*Areca Catechu*), *c.* Remains of perianth. *f.* Pericarp. *p.* Ruminated albumen of the seed. *e.* Embryo.——*Fig.* 590. Embryo of the Lime-tree (*Tilia europæa*). *c, c,* Cotyledons, each with five lobes arranged in a palmate manner. *r.* Radicle. *Fig.* 591. Section of the fruit of the Oat. *p.* Plumule. *r.* Radicle. *s.* Scutellum.——*Fig.* 592. Germinating embryo of the Oat. *r.* Rootlets coming through sheaths, *co.* *c* Cotyledon. *g.* Young stem.——*Fig.* 593. Embryo of *Triglochin.* *r.* Radicle. *f.* Slit corresponding to the plumule. *c.* Cotyledon.

A peculiar development of part of the cotyledon, called the *scutellum* (*fig.* 591, *s*), separates the embryo from the endosperm in the seed of the Grasses.

The inferior extremity of the radicle is usually rounded (*fig.* 593, *r*), and it is through this point that the rootlets, *r*, burst in germination (*fig.* 592). The radicle is usually much shorter than the cotyledon, and generally thicker and more sturdy; but in some embryos it is as long as the latter, or even longer, in which case the embryo is called *macropodous.*

(b) *The Dicotyledonous Embryo.*—These embryos vary generally in form: those of the Bean and Almond (*fig.* 594) are more or less ovoid; the embryo consists of two nearly equal cotyledons, *c*, between which lies a small axis or *tigellum*, *t*, the upper part of which, *g*, is the *plumule*, and the lower, *r*, the *radicle*. The lower part of the tigellum upon germination appears as a little stalk, supporting the cotyledons; it is termed the *hypocotyledonary axis*, or *hypocotyl*. The lower part of the plumule forms the *epicotyl*.

In the great majority of cases the two cotyledons are of nearly equal size, as in the Pea (*fig.* 16, *c*, *c*), but in the embryos of *Trapa*, some *Hiræas*, &c. (*fig.* 595, *c'*, *c*), they are very unequal. Again, while the cotyledons usually form the greater part of the embryo (*fig.* 16, *c*, *c*), in other instances, as in the seeds of *Pekea butyrosa* (*fig.* 597, *c*), they form but a small portion. In those of *Carapa* (*fig.* 596), again, the two cotyledons become united more or less completely into one body, so that the embryo appears to be monocotyledonous; but its nature is readily ascertained by the different position of the plumule in the two cases; in the true monocotyledonous embryo the plumule is situated laterally (*fig.* 591, *p*); but here (*fig.* 596, *g*) it is between the cotyledons. The embryos of some parasitic plants, e.g. *Cuscuta*, have no cotyledons.

FIG. 594.

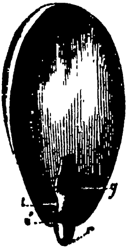


FIG. 595.

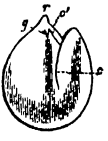


FIG. 596.

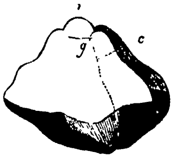


FIG. 597.

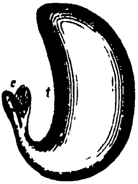


Fig. 594. The embryo of the Almond (*Prunus Amygdalus*), from which one of the cotyledons has been removed. *c*. The cotyledon which has been left. *r*. Radicle. *g*. Plumule. *t*. Tigellum. *c'*. Scar left by the removal of the other cotyledon.——*Fig.* 595. Vertical section of the embryo of a species of *Hiræa*. *c'*. Large cotyledon. *c*. Small cotyledon. *g*. Plumule. *r*. Radicle.——*Fig.* 596. Vertical section of the embryo of *Carapa guianensis*, showing the almost complete union of the cotyledons, the line, *c*, only dividing them. *r*. Radicle. *g*. Plumule.——*Fig.* 597. The embryo of *Pekea butyrosa*. *t*. Large tigellum. *c*. Rudimentary cotyledons.

When no albumen is present in the seed the cotyledons are usually thick and fleshy, as those of the Bean and Almond (*fig.* 594); in albuminous seeds they are thin and foliaceous, as those of the

Lime (*fig.* 590, *c*, *c*). Foliaceous cotyledons are frequently provided with veins, and stomata may be also sometimes observed in their epidermis; but these structures are rarely to be found in fleshy cotyledons. Fleshy cotyledons serve a similar purpose to the albumen, by acting as reservoirs of nutritious matters for the use of the young plant during germination; hence, when the albumen is absent, the cotyledons are generally proportionately increased in size.

The cotyledons of dicotyledonous plants are commonly sessile, and their margins are usually entire, but exceptions occur to both these characters; those of *Geranium molle* (*fig.* 599, *p*) are petiolate; those of the Lime (*fig.* 590, *c*, *c*), and those of the Geranium (*fig.* 599, *c*) are lobed. Their positions relatively to each other also vary. Generally, they are placed parallel, or face to face, as in the Almond (*fig.* 594), Pea (*fig.* 16), and Bean; but they frequently depart widely from such a relation, and assume other positions. Each of the cotyledons may be either *reclinate*, *conduplicate*, *convolute*, or *circinate*. These are the commoner conditions, and in such instances both cotyledons are either folded or rolled in the same direction, so that they appear to form but one body; or in rare cases they are folded in opposite directions, and become *equitant* or *obvolute*; sometimes other still more complicated arrangements occur.

FIG. 598.

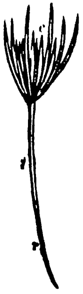


FIG. 599.

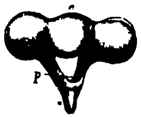


Fig. 598. The so-called polycotyledonous embryo of a species of *Pinus* beginning to germinate. *c.* Cotyledons. *r.* Radicle. *t.* Tigellum.——*Fig.* 599. The embryo of *Geranium molle*. *c.* Cotyledons, each of which is somewhat lobed, and furnished with a petiole, *p*. *r.* Radicle.

FIG. 600.

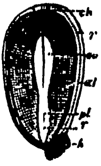


FIG. 601.

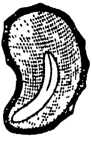


FIG. 602.

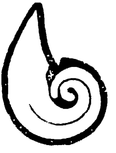


Fig. 600. Vertical section of the seed of the Pansy or Heartsease. *h.* Hilum. *pl.* Embryo with its radicle, *r*, and cotyledons, *co*. *ch.* Chalaza. *al.* Albumen. *ra.* Raphe. The embryo is erect or homotropous.——*Fig.* 601. Vertical section of the seed of the Poppy, with the embryo slightly curved in the axis of albumen.——*Fig.* 602. Vertical section of the seed of *Bunias*, showing its spiral embryo.

The position of the radicle in relation to the cotyledons is also liable to much variation. The radicle may follow the same direction as the cotyledons, or a different one. In the former case, if the embryo is straight, the radicle is more or less continuous in a straight line with the cotyledons, as in the seeds of the Pansy (*fig.* 600, *r*); if, on the contrary, the embryo is curved, the radicle is curved also (*fig.* 601); the curvature of the radicle of *Bunias* (*fig.* 602) is so great that a spiral is formed. Where the direction of the cotyledons and radicle is different, the latter may form an acute, obtuse, or right angle to them; or be folded back so as to lie parallel to the cotyledons, in which case the radicle may be either applied to their margins, as in the seed of the Wallflower (*fig.* 604, *r*), when the cotyledons are said to be *accumbent*; or against the back of one of them, as in that of *Isatis* (*fig.* 603, *r*), when they are termed *incumbent*.

FIG. 603.

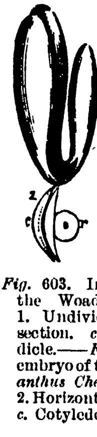


FIG. 604.

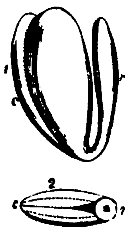


Fig. 603. Incumbent embryo of the Woad (*Isatis tinctoria*). 1. Undivided. 2. Horizontal section. *c.* Cotyledons. *r.* Radicle.——*Fig.* 604. Accumbent embryo of the Wallflower (*Cheiranthus Cheiri*). 1. Undivided. 2. Horizontal section. *r.* Radicle. *c.* Cotyledons.

Relation of the Embryo to the other Parts of the Seed, and to the Fruit.—It must necessarily happen that when albumen is present, the size of the embryo is in inverse proportion to it; in the seeds of Grasses (*fig.* 591) we have a large deposit of albumen and but a small embryo, while in those of the Nettle (*fig.* 605) the embryo is large and the albumen very small. The embryo may be either external to the albumen (*figs.* 591 and 608), and thus in contact with the integuments, as in the seeds of Grasses, in which case it is described as *external*; or it may be surrounded by the albumen, except on its radicular extremity, as in the Pansy (*fig.* 600), when it is *internal*.

The embryo is *axial* when it has the same direction as the axis of the seed, as in those of the Pansy (*fig.* 600, *pl*); when this condition is not found, it is *abaxile* or *eccentric*, as in those of *Rumex* (*fig.* 606, *pl*). In the latter case, the embryo is frequently altogether on the outside of the albumen, and directly below the integuments, as in the seeds of *Mirabilis Jalapa* (*fig.* 607, *e*) and *Lychnis* (*fig.* 608, *emb*), when it is described as *peripherical*.

We have already observed that in a straight embryo the radicle as a rule is turned towards the micropyle (*fig.* 606, *r*), and the cotyledonary extremity is then directed to the chalaza, *ch*. Some apparent exceptions to these relative positions occur among the *Euphorbiaceæ* and a few other plants; but such are merely accidental deviations arising from certain irregularities in the course of the development of the parts of the seed.

While the relation of the radicle and cotyledonary portion is thus seen to be generally constant, it necessarily happens, from the varying relation which the *hilum* bears to the micropyle and chalaza, that its relation to the radicle and cotyledonary portion of the embryo must also vary. In orthotropous seeds, as those of *Rumex* (*fig.* 606), the chalaza and hilum coincide with each other; the radicle is turned towards the apex of the seed, and the cotyledonary portion to the chalaza and hilum; in this case the embryo is said to be *antitropous* or *inverted* (*figs.* 476 and 606). In anatropous seeds, as those of the Pansy (*fig.* 600), where the micropyle is contiguous to the hilum, *h*, and the chalaza, *ch*, at the opposite extremity, the radicle, *r*, points towards the hilum or base of the seed, and the embryo is said to be *erect* or *homotropous*. In a campylotropous seed, where the chalaza and micropyle are both near to the hilum, as in those of *Lychnis* (*fig.* 608), the two extremities of the embryo, which in such cases is generally peripherical, become also approximated, and it is said to be *amphitropous*. When we wish to know the direction of the embryo it is at once determined by ascertaining the position of the hilum, chalaza, and micropyle.

Fig. 606.

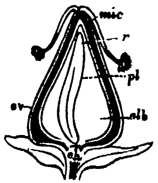


Fig. 605.

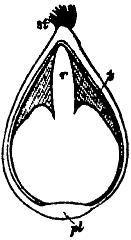


Fig. 607.

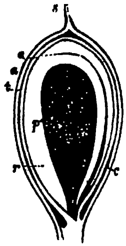


Fig. 608.

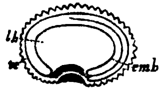


Fig. 605. Vertical section of the fruit of the Nettle, containing a single seed. *t*. Integuments of the seed. *pl*. Placenta. *r*. Radicle. *st*. Stigma. *Fig.* 606. Vertical section of the fruit and solitary erect orthotropous seed of the Dock (*Rumex*). *ov*. Pericarp. *mic*. Micropyle. *pl*. Embryo which is inverted or antitropous, and turned towards one side of the albumen, *alb*. *ch*. Chalaza. *r*. Radicle.——*Fig.* 607. Vertical section of the carpel of *Mirabilis Jalapa*, containing one seed. *a*. Pericarp. *s*. Style. *e*. Peripherical embryo with its radicle, *r*, and cotyledons, *c*. *p*. Albumen. *t*. Integuments of the seed.——*Fig.* 608. Vertical section of the seed of *Lychnis dioica*. *te*. Integuments. *emb*. Embryo on the outside of the albumen, *alb*. The embryo is amphitropous and peripherical.

We have now, lastly, to explain the different terms which are in use to express the relations which the embryo bears to the cavity or cell in which it is placed. The radicle is said to be *superior* or *ascending*, as in the seeds of the Nettle (*fig*. 605, *r*) and *Rumex* (*fig*. 606, *r*), when it is directed towards the apex of the cell or pericarp; *inferior* or *descending* when it points to the base; *centripetal* if turned inwards towards the axis or centre; and *centrifugal* when it is turned towards the sides. These relations of the embryo to the other parts of the seed, and to the cavity or cell in which it is placed, are sometimes of much practical importance.

(c) *The Polycotyledonous Embryo*.—In the seeds of the Gymnosperms, as already mentioned, there are often several cotyledons, and this may occur either as an irregular character, or as a regular condition, as in those of many members of the *Coniferæ* (*fig*. 598, *c*), where we frequently find six, nine, or even fifteen; hence such embryos have been termed *polycotyledonous*. In all cases where the number of cotyledons is more than two, they are arranged in a whorl (*fig*. 598, *c*). *Taxus*, the Yew-tree, has only two cotyledons.

BOOK II

ANATOMY OF PLANTS

CHAPTER I

THE VEGETABLE CELL

If we study the life-history of the simplest or the most complex plant with which we can become acquainted, we find that at some time or other in its existence it is found in the form of a minute portion of jelly-like substance, in some cases motile, in others incapable of locomotion. The zoospores and zoogonidia of the Algæ exhibit this structure. The gametes which are developed upon the filamentous Seaweeds are also such little naked masses. In the lowest plants, such as *Ulothrix* (*fig.* 609), these are ovoid bodies, furnished with long narrow appendages, by means of which they swim actively about in water. The jelly-like substance of which they are composed is capable of carrying on all the processes of their life, and is, in fact, the *living substance*; it is called *protoplasm.* Many of the small reproductive bodies already described differ from these free-swimming organisms in having the protoplasm clothed by a thin, almost structureless membrane, which the living substance forms round itself. We have in these two parts, one

Fig. 609.

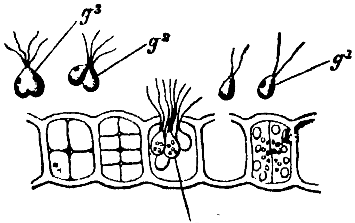


Fig. 609. Part of a filament of *Ulothrix* from which the gametes, *g*, are escaping. g^1. Free gamete. g^2, g^3. Gametes conjugating.

living, the other non-living. All such structures are known as *cells*.

When one of these cells has existed for a time, it becomes septated into two by the formation of a partition-wall of the same substance as the membrane which clothes it, the septum being formed by the protoplasm just as is the original membrane. Usually the two cells arising from such septation remain connected with each other; each in turn gives rise to another in the same way, and by the continuation of this process we get a mass made up of a number of cells. These structural units are not, however, completely distinct, for the protoplasm of each is in connection with that of its neighbour by delicate filaments which penetrate the septa, or cell-walls, so that the living substance of such a mass is organically continuous throughout, being supported by the membranes which it has formed, which constitute indeed a kind of skeleton.

FIG. 610.

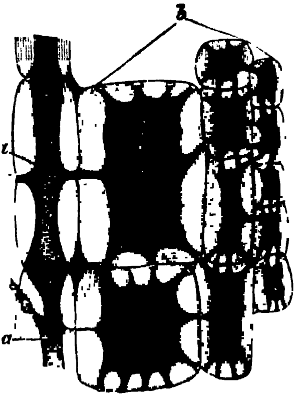


Fig. 610. Semi-diagrammatic longitudinal section of an old and stout portion of *Ceramium rubrum*, showing continuity between the protoplasmic contents of the axial or central cells, *a*, *a*, at their ends; and laterally with the cortical cells, *b*, by protoplasmic threads, and also that of the cortical cells *inter se* by threads radiating from the central mass in each cell. After T. Hick.

A section through such a mass shows the appearance of a number of chambers, each occupied by a portion of the living substance. It needs a very high magnification to distinguish the connecting threads or strands, which are of extreme tenuity (*figs.* 610 and 611). In general, we may say then that a plant is built up of an aggregation of such cells.

Some plants do not always form the dividing septa, so that in them we have many pieces of protoplasm, or *protoplasts*, connected closely with one another, and having only a common membrane or cell-wall surrounding the whole. Such a plant-body is called a *cœnocyte*. Others form relatively few septa, so that each division of the plant-body contains many protoplasts. Usually each protoplast occupies a separate chamber. In the higher forms subsequent changes in the character of the septa give rise to very different appearances in the cells, the latter showing great differences in size and degree of development. In all cases, however, they arise in the manner described, by the activity of the protoplasm.

We can thus see that the living substance is the essential part of the cell, and all other structures found in connection with it are only subordinate to the requirements of the protoplasm.

In the simplest forms, each protoplast discharges all the vital processes of the plant. As, however, complexity of the plant-body increases, there may be observed a division of labour, particular protoplasts taking up one, others another, duty. Some are particularly concerned in nutrition, others in reproduction, and so on. This division of labour is the clue to the differences of structure and appearance which we find in different parts of the plant-mass, cells being modified in relation to the work which ultimately falls to their share. Thus all differentiation of structure is to be traced to division of labour.

FIG. 611.

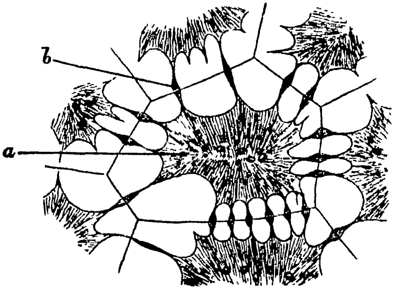


Fig. 611. Continuity of the protoplasm of contiguous cells of the endosperm of a Palm seed (*Bentinckia*). *a.* Contracted protoplasm of a cell. *b.* A group of delicate protoplasmic fibrils passing through a pit in the cell-wall. (Highly magnified, after Gardiner.)

In the older parts of plants we find the cells consisting of the wall alone, the protoplasm having disappeared. Such cells are, of course, not living.

It is most convenient to study first the vegetable cell as it exists in a portion of the higher plants, such as the younger part of a stem or root. If we cut a section of such a structure we find the cells all alike and all presenting the following features: 1. The limiting membrane or cell-wall. 2. The contents, consisting of the protoplasm and various bodies embedded in it or surrounded by it (*figs.* 612–614). The protoplasm, being the essential part, may be examined first.

FIG. 612.

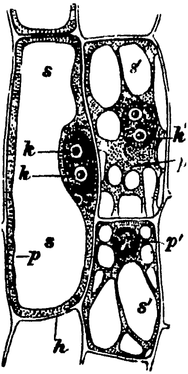


Fig. 612. Cells from the root of *Fritillaria imperialis*. *h*. Cell-wall. *k'*. Nucleus. *k*, *k*. Nucleus with nucleoli. *p*. Primordial utricle. *p'*, *p'*. Protoplasmic threads. *s*, *s*. Cell-sap cavity. *s'*, *s'*. Vacuoles. After Sachs.

THE PROTOPLASM.—In the young state of the cell the protoplasm fills it, and appears as a nearly transparent jelly-like material, somewhat granular in character, and saturated with water. This condition is only transitory. Very soon, in consequence of continual absorption of water, the cell, kept turgid and stretched by the internal pressure, increases in size; the water accumulates in drops, which gradually become larger, so that cavities appear in the substance of the protoplasm, which soon fuse together, forming one or more *vacuoles* filled with a fluid called the *cell-sap*. In such cells the protoplasm often forms only a lining to the cell-wall, the centre of the cell being occupied by a single large vacuole (*fig.* 612). The protoplasm thus lining the cell was formerly called the *primordial utricle*.

In the substance of the protoplasm, whether filling the cell or not, there exists somewhere a specially differentiated portion called the *nucleus* (*fig.* 612, *k*), and frequently other less differentiated portions, distinct from the main portion of the protoplasm, known as *plastids*. The bulk of the protoplasm, to

FIG. 613.

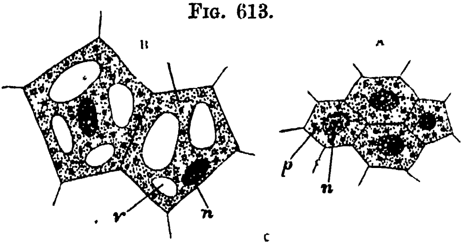


Fig. 613. Vegetable cells. A. Very young. B. A little older, showing commencing formation of vacuole. *p*. Protoplasm. *n*. Nucleus. *v*. A vacuole.

distinguish it from these specialised portions, is generally called the *cytoplasm*. It is not of the same consistency throughout, a generally firmer portion lying next to the cell-wall being known as the *ectoplasm*. A similar firm layer may frequently be detected round the vacuole. The exact chemical composition of protoplasm cannot be ascertained, as analysis involves its death, and this is attended by changes in its substance. It contains carbon, hydrogen, oxygen, nitrogen, and probably sulphur and phosphorus. Enclosed in it are always varying quantities of organic substances, such as proteids, fats, carbohydrates, and small portions of various inorganic salts. These various constituents are connected with the nutritive processes of the cell, or its *metabolism*, and hence differ greatly in nature and amount from time to time.

FIG. 614.

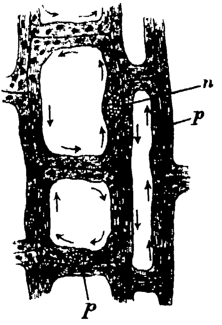


FIG. 615.

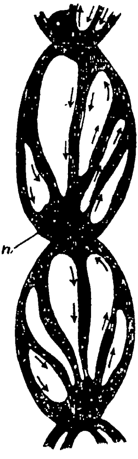


Fig. 614. Cells from leaf of *Elodea* ; the arrows show the direction of the rotation of the protoplasm. *n*. Nucleus. *p*. Protoplasm or primordial utricle, in which are embedded numerous chloroplasts. (× 300.)——*Fig*. 615. Two cells from a staminal hair of *Tradescantia* The arrows indicate the direction of the circulation of the protoplasm. *n*. Nucleus. (× 300.)

In the case of the free-swimming protoplasts with which we began the study of protoplasm, we see that they are in active movement. As the protoplasm becomes enclosed in cell-walls this motility is, of course, less and less obvious. Indeed, in most cells it can hardly be distinguished. There is reason to suppose, however, that protoplasm, wherever existing, is in constant motion. In many of the constituent cells of even the higher plants this motility can be observed. In certain of the cells forming the leaves of many water-plants, e.g. *Vallisneria*, *Nitella*, *Elodea* (*fig.* 614), and others, a streaming movement of the granules the protoplasm contains can be detected with ease. In other plants of terrestrial habit, such as *Tradescantia* and *Chelidonium*, a streaming of the protoplasm is observable (*fig.* 615). Such movements are spoken of as *rotation* when the stream flows uniformly round the wall of the cell, or as *circulation* when the path has a more complicated course.

Somewhere in the cell there is always to be be found a specially differentiated portion of the protoplasm known as the *nucleus* (*figs.* 614 and 615, *n*). It may lie in the centre, when it is attached to the sides by bands or threads of protoplasm; or it may lie embedded in the layer which lines the cell. This body has a more definite structure than the rest of the cytoplasm; it is bounded at the surface by a delicate membrane, which is thought, however, to be a denser layer of the protoplasm of the cell rather than to belong to the nucleus itself. The latter consists of two substances which differ from each other in their power of staining with different reagents. The bulk of it is composed of a semi-fluid material known as *nucleoplasm*, in which is embedded a network of fibrils. The latter are composed of a hyaline substance in which lie close to each other a number of granules or discs which stain deeply with many colouring matters. The fibrils contain the granules in such large proportion that except with very high magnification the latter cannot be distinguished, and consequently the whole fibril appears stained. These fibrils are generally said to be composed of *chromatin*, the name having reference to nothing more than this reaction to stains.

One or more small deeply staining bodies, termed *nucleoli*, are found in each nucleus, sometimes being very prominent, and at other times hardly distinguishable from the nodes of the fibrillar network.

Chemically the nucleus much resembles the rest of the protoplasm, but, in addition to the substances found to be present in the latter, the nucleus contains a body known as *nuclein*, of which phosphorus is a constituent.

Associated with the nucleus there have been observed in certain cases two very small bodies lying usually side by side at some point of its margin. These are called the *centrospheres*. Each is spherical and hyaline, with a distinct outline, and contains in its interior a central smaller body. This is known as the *centrosome.*

In rare cases a true cell may contain several nuclei. This occurs in consequence of direct division or fragmentation of the original nucleus. It is seen only in old cells.

Besides these typical constituents the protoplasm of many cells contains other differentiated structures, known as *plastids.* These are special bodies which are charged with some definite function, and point to an early division of labour in the cell. They are of a somewhat similar structure to the nucleus, being formed of a fibrillar network supported by a ground substance. Some of them are colourless, others impregnated with different colours. The first are called *leucoplasts*, the others *chloro-* or *chromoplasts*, according to their hue, the green ones or chlorophyll bodies being thus distinguished from all others (*fig.* 614).

The plastids must be distinguished from other cell-contents such as will be described later. They are independent bodies charged with the performance of definite functions; they always lie in the substance of the protoplasm, and not in the vacuoles; they have a power of multiplication by division, quite apart from the activity of the cell-protoplasm. Their shape and their dimensions vary extremely in different cells, but they are generally spheroidal or discoid. There seems to be but little difference between the chloroplast and the leucoplast, the latter being formed in parts to which light has no access, the former occurring in parts exposed to light. In the presence of light the leucoplasts can develop a green colouring matter, becoming chloroplasts.

The colouring matters of the different plastids can be extracted by various solvents, leaving a colourless basis. The green colouring matter of the chloroplasts, which is known as *chlorophyll*, can be dissolved out by alcohol, benzol, and other fluids. The red or brown colour of the chromoplasts of the red or brown seaweeds is soluble in cold distilled water. They are found after removal of these pigments to contain chlorophyll as well.

Chromoplasts of various colours give their tints to many of the brilliant floral leaves, particularly those which are yellow or scarlet. These are generally derived from chloroplasts, the leaves when young being green.

We have seen that, at some period of their life, many of the lowliest plants consist only of a small ovoid mass of protoplasm with two appendages or flagella at one end. These flagella, like the rest of the cell, are composed of protoplasm, and are especially capable of vigorous movement, showing a certain differentiation with that object. Other naked masses of protoplasm are not furnished with these flagella, but possess much shorter, more delicate threads known as *cilia*, which are placed either all over their surface, as in the case of the zoocœnocytes of *Vaucheria*, or form a ring near one end, as in the zoospores of *Œdogonium* (*fig.* 666, *c*). In many of such naked cells there is a specially coloured corpuscle, usually red, known as an *eye-spot*. In others a special vacuole in the protoplasm shows a rhythmical enlargement and contraction. This is known as a *contractile vacuole*. It recalls a similar structure in the lowest animal organisms.

THE CELL-WALL.—We have seen that in most cases the first evidence of the vital power of the protoplasm is the formation of a membrane which surrounds it on all sides. This is known as the *cell-wall*. It is chiefly composed of a substance known as *cellulose*, with which in most cases other bodies known as *pectoses* are more or less closely incorporated. Cellulose has a very complex molecule, into which only the elements carbon, hydrogen, and oxygen enter. the latter two existing in the same proportion as they do in water; this body is consequently a member of a group of substances known as *carbohydrates*. Its chemical formula is often written $C_6H_{10}O_5$, though probably it should be some multiple of this. Sugar and starch are other members of the same group.

Cellulose is a colourless transparent substance, easily permeable by water and by substances in solution in it. It can be stained violet by iodine in the presence of sulphuric acid or chloride of zinc.

The solid portion of the cell-wall contains a varying quantity of water. Various theories have been advanced as to the way in which the latter is combined with the other constituents. Nägeli has suggested that the wall is composed of *micellæ*, or needle-shaped crystals of cellulose, arranged with their long axes at right angles to the surface of the wall, and surrounded by a thin film of water. According to Strasburger the particles of cellulose are arranged in a network, water occupying its meshes. In either case the quantity of water is capable of considerable increase or diminution, and the wall can be made to swell up by causing it to imbibe more fluid. This can be brought about by exposing it to the action of strong acids, such as sulphuric acid.

A different view of the composition of the cell-wall has been advanced in recent years by Wiesner. He holds that the substance of cell-wall as it is first formed consists of rows of granular bodies which he terms *dermatosomes*, which are united together and surrounded by protoplasm, and which ultimately become cellulose. On this hypothesis the cell-wall is living while young and growing. The protoplasm thus exists between particles of cellulose, and holds water in its substance.

FIG. 616. FIG. 617. FIG. 618. FIG. 619.

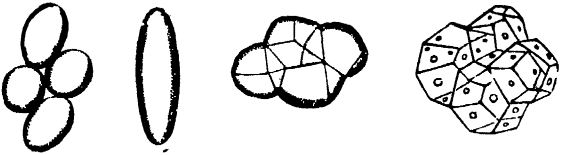


Fig. 616. Rounded cells.——*Fig.* 617. Elliptic or oblong cell.——*Figs* 618, 619. Polygonal cells in combination: those of the latter figure being pitted.

As the cells grow there is a continuous formation of cellulose, due, like its first formation, to the vital activity of the protoplasm. By irregularity of growth, due to internal causes bringing about greater possibility of stretching in certain places, cells become of various forms; when the growth is uniform, or nearly so, in all parts of the cell-wall, we have a *spherical* or *rounded* cell (*fig.* 616); but when it is greater at the two extremities than at the sides, the form is *oval* or *oblong* (*fig.* 617). In both these cases, also, the cells are almost, or entirely, free from external pressure. But under other circumstances, in consequence of the mutual pressure of surrounding cells, they assume a *polygonal* form (*figs.* 618 and 619), the number of the angles depending upon the number and arrangement of the contiguous cells.

FIG. 620. FIG. 621.

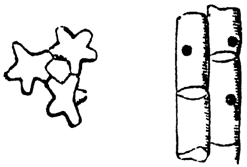


Fig. 620. Stellate cells.——*Fig.* 621. Cylindrical cells. The small rounded body in the interior of three of these cells is the nucleus.

When growth takes place on all sides of the cell-wall, but certain spots are more extensible than the rest, the internal pressure causes protrusions at those places, so that we have rays projecting from them in various directions, and they acquire a more or less regular star-like shape (*fig.* 620); such cells are called ***stellate.*** The rays may be situated in one plane, or project from all sides of the cell. Such cells rarely have the rays occurring at regular intervals, or all of one length, but various degrees of irregularity occur.

When the growth takes place chiefly in one direction, we have cells which are elongated, either horizontally or vertically. Of the latter we have such forms as the *cylindrical* (*fig.* 621) and the *fusiform* (*fig.* 622): by the mutual pressure of contiguous cells, the latter often become *prismatic.* In many Fungi the common cell-wall of the cœnocyte is elongated, very delicate and thread-like, and either simple or branched (*fig.* 623).

FIG. 622.

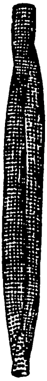


FIG. 623.

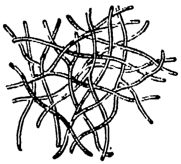


FIG. 624.

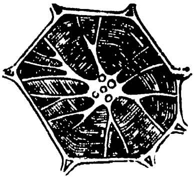


FIG. 625.

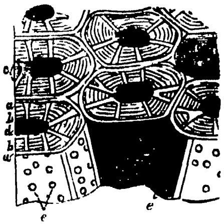


FIG. 626.

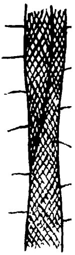


Fig. 622. Elongated fusiform cells.——*Fig.* 623. Fibrilliform cells (*hyphæ*). *Fig.* 624. Transverse section of a thick-walled cell of the pith of *Hoya carnosa.* From Von Mohl.—— *Fig.* 625. Thick-walled cells from the fruit of a Palm. *a, a.* Cell-walls. *b, b.* Concentric layers of thickening. *c.* Canals extending from the central cavity to the inside of the wall of the cell. *d.* Cavity of the cell. *e, e.* External dotted appearance. From Unger.——*Fig.* 626 Striated fibres from bast of Lime tree.

When the cell has attained its full size, or in some cases while it is still growing in surface, its wall becomes thickened by the deposition of successive layers over those already formed.

A transverse section of many cell-walls shows traces of this mode of thickening, the successive layers appearing as shells of substance lying one upon another. Such a cell-wall is said to be stratified (*fig.* 624 and 625). Viewed longitudinally, the walls often appear covered with delicate oblique striations which may run regularly in one direction only, or may be crossed by others. This is due to the way in which the protoplasm deposits the new particles of cellulose upon the layers already existing, a succession of spiral bands being laid down with their edges in contact. Such striations can be well observed in many of the elongated cells or fibres which form part of the soft portions of the vascular bundles of the higher plants (*fig.* 626).

FIG. 627. FIG. 628. FIG. 629. FIG. 630. FIG. 631.

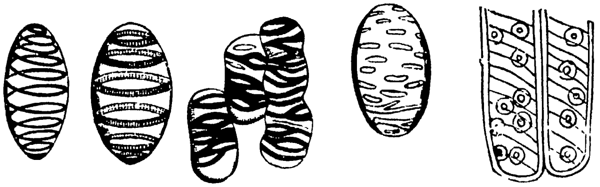


Fig. 627. Spiral cell.——*Fig.* 628. Annular cell.——*Fig.* 629. Reticulated cells.——*Fig.* 630. Pitted and reticulated cell.——*Fig.* 631. Wood-cells of the Yew (*Taxus baccata*). After Von Mohl.

FIG. 632. FIG. 633. FIG. 634. FIG. 635. FIG. 636.

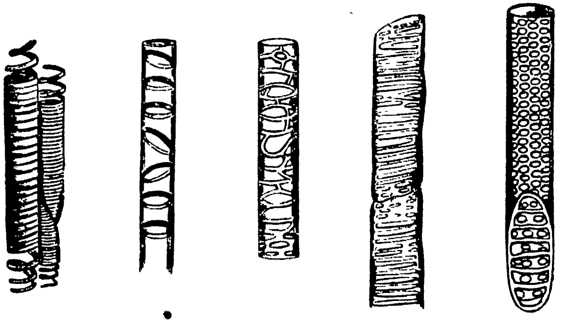


Fig. 632. Simple spiral vessels.——*Fig.* 633. Annular vessel.——*Fig.* 634. Reticulated vessel.——*Fig.* 635. Cylindrical scalariform vessels of the Vine.——*Fig.* 636. Pitted tracheïd terminating obliquely, and showing that the partition wall has been incompletely absorbed.

It generally happens that, when cell-walls are being thickened, the new deposits of cellulose are not laid down uniformly over the surface, but instead form ridges or prominences of various patterns, with unthickened portions between them. The thickening may take the form of a spiral band, winding obliquely round the interior of the cell; it may be deposited in the form of rings placed regularly along its greater axis; or it may be laid down irregularly, giving rise to particular patterns upon the wall. These forms are known as spiral, annular, and reticulated thickenings respectively (*figs.* 632–634). In other cases the thickening may extend over the greater surface of the wall, leaving only small unthickened spots. Such a cell-wall is said to be pitted. When two cells side by side are undergoing thickening simultaneously, the thick and thin places of the separating wall correspond in position, and the pits appear as delicate canals which in some cases serve as means of communication between the cells (*figs.* 625 and 637).

FIG. 637.

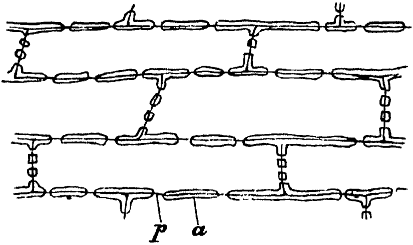


Fig. 637. Cells whose walls are in process of thickening. The thick and thin places on the separating wall correspond in position. *p*. Pits or thin places. *a*. Thickening deposit.

In the cell-walls of the wood-cells of certain trees we find pits of peculiar formation, each appearing to be surrounded by a ring. These are known as *bordered pits*. The cells in which they occur are long fusiform elements, and are characteristic of the secondary wood of the *Coniferæ*. The appearance is produced by circular patches of the cell-wall remaining thin after the general thickening has commenced, and the rim of the thickening layer bounding them growing obliquely inwards, leaving ultimately only a narrow orifice in the centre; or, in other words, the opening of the pit into the interior of the cell is narrow, and the pit itself is funnel-shaped (*fig.* 639, *a*, *b*, *c*). As these thickenings always occur in pairs, that is, one on each side of the cell-wall, they appear as two watch-glasses would do if placed rim to rim, and separated by a thin sheet of paper. To carry out the comparison completely, however, the watch-glasses must be supposed to be perforated in their centres (*fig.* 639, *b*). The central spot, which appears lighter than the rest of the pit when examined by transmitted light, is caused by the light having to pass only through the thin unthickened cell-wall or membrane (*fig.* 639, *c*, *w*), while the darker colour of the border is caused by the light having to pass through the thicker substance of the rim. The membrane has a separate central thickening called the *torus*, which thus lies inside the pit, and is about as large as the central opening, which it can therefore block up when great tension exists on either side of the membrane, forcing it outwards. In very old wood this intervening membrane often becomes absorbed, and then direct communication between the adjoining cells is possible.

FIG. 638.

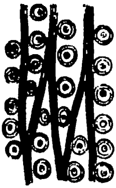


FIG. 639.

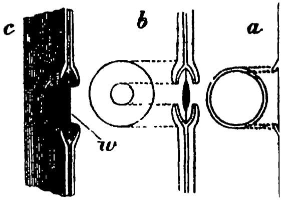


Fig. 638. Bordered pits of the wood-cells of the Pine, with a single row of discs on each cell.——*Fig.* 639. Bordered pits of the wood-cells of the Pine (diagram). *a*. Young stage with unthickened cell-wall or membrane. The straight part on the right shows a section through a pit with the rim beginning to project; the circle on the left shows the rim in surface view. Dotted lines connect corresponding parts. *b*. Older stage showing the membrane with its torus. *c*. Semi-profile view, showing position of membrane, *w*. After Sachs.

These bordered pits occur either in single (*fig.* 638) or in double or triple rows. In those cases where there is more than one row of them, those in each row may be either on the same level, as is usual, or at different levels, and hence alternate to each other, as in the Araucarias and allied trees.

Cells presenting such a characteristic appearance are of universal occurrence in the wood of the *Coniferæ* and *Taxaceæ*, where they can be most distinctly observed. But somewhat similar bordered pits of smaller size may be found also in many other Phanerogams.

The material of which the cell-wall is originally composed is a mixture of cellulose with various pectic bodies. The reactions by which cellulose may be recognised are—

1. It is insoluble in water, weak acids or alkalies, alcohol, ether, benzol or other aromatic liquid, but dissolves in ammoniacal solution of oxide of copper (Schweizer's reagent).

2. It is permeable by water, extensible, and elastic.

3. It swells up and slowly dissolves when treated with strong sulphuric acid.

4. It stains violet when treated with sulphuric acid and iodine, or with a solution of iodine in potassic iodide and chloride of zinc.

5. When it is viewed by polarised light it causes the rays to be deflected to the left.

The pectic bodies, chiefly consisting of pectose, pectin, and pectic acids, are not soluble in Schweizer's reagent, but are slowly dissolved by the successive action of acids and alkalies. They do not stain violet with iodine, either alone or in conjunction with sulphuric acid or the chlorides of the heavy metals.

The cell-wall seldom remains simple; soon after formation changes occur in it, admixture of mineral substances to a considerable extent often rapidly taking place. The chief of these are salts of calcium, usually the oxalate, but often the carbonate. Some cell-walls show a copious deposit of regular crystals of one of these—such are the cells of the bulb-scales of the Onion, the fibres of the bast of *Ephedra*, and others (*fig.* 640). In many plants copious deposits of silica are found in the cell-wall, notably in the epidermal cells of Grasses and *Equisetaceæ*. In some plants of the Nettle family curious cellulose projections occur in some of the cells of the epidermis which contain irregular masses of calcium carbonate. These are known as *cystoliths* (*fig.* 642).

Besides these admixtures of foreign substances, cell-wall is found to contain other bodies derived from changes in its cellulose or pectose constituents. Of these, three are especially prominent—lignin, cutin, and mucilage. Lignin is the material which is especially characteristic of wood-cells. It is permeable by water very readily, but, unlike cellulose, it cannot retain much in its substance, nor can it swell up under the influence of sulphuric acid. It can be recognised by turning red when treated with phloroglucin and hydrochloric acid. The wall of a wood-cell does not consist entirely of lignin, but of a cellulose basis which is largely impregnated with this substance. By the action of nitric acid and chlorate of potash the lignin can be dissolved, leaving the cellulose framework.

Cutin is found chiefly in the external layers of the thickened epidermal cells, and is also met with in the walls of cork cells, where it is frequently associated with a certain amount of lignin. It differs from cellulose in many points: it is but slightly permeable by water, and it stains yellow instead of violet when treated with iodine and sulphuric acid. It turns yellowish-brown when acted upon by strong alkalies such as caustic potash.

FIG. 640.

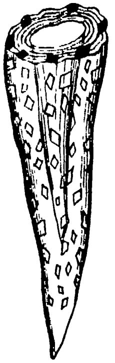


FIG. 641.

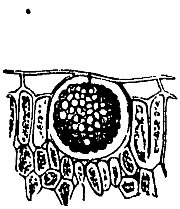


FIG. 642.

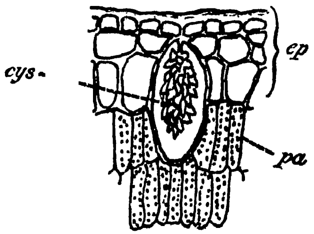


Fig. 640. Bast cell of *Ephedra* with crystals embedded in the wall.——*Fig.* 641. Cystolith from *Parietaria officinalis*. *Fig.* 642. Cystolith from the leaf of *Ficus elastica*. *ep*. Three-layered epidermis. *pa*. Parenchyma of leaf. *cys*. Cystolith.

Like lignin, cutin is soluble in warm nitric acid and chlorate of potash.

Mucilage is found in the cell-walls of certain layers of the coats of such seeds as linseed, and in the cells of many Algæ. It absorbs water greedily and swells up considerably. It gives a violet colour with iodine and sulphuric acid, as cellulose does, differing from the latter chiefly in the ease with which the absorption of water is brought about. In some cells the mucilaginous degeneration of the cell-wall goes so far as to lead to the production of gum, which is soluble in water. Exudations of gum produced in this way are very common on Cherry trees.

A peculiar modification of the cell-wall can be easily observed between contiguous thickened cells, constituting the *middle lamella*. This occupies the position of the original cell-wall, and at first sight might be taken to be the latter, after several thickening layers have been deposited upon it. This is not, however, the case, for the thickened wall has been the seat of much chemical alteration. The nature of the middle layer varies; in adult cells which have not become lignified or otherwise altered it consists of a compound of pectic acid and calcium. This layer can be distinguished between even very young cells, by appropriate reagents.

The cell-wall is often found to be impregnated with wax, which in some cases is so plentiful as to form a layer of particles on the external surface. This can be seen in the bloom of certain fruits, such as the Plum and the Grape; also on the leaves of the Wax Palm.

Certain modifications of cellulose also occur, unmixed with any of these derivatives. The walls of the hyphæ of Fungi afford an example of these; the cellulose, sometimes called *fungus cellulose*, does not turn violet when treated with iodine and sulphuric acid. In the walls of certain cells, such as those of the bast of *Lycopodium*, the endosperm of the Pæony, and the cotyledons of some of the *Leguminosæ*, a variety of cellulose is found which stains blue with iodine alone.

Chemically regarded, the cell-wall is thus seen to be very complex in composition. Originally it consists mainly of cellulose, with a small admixture of pectoses; as it grows older this simplicity disappears, and it is found to be a mixture of those primary constituents with various products of their decomposition, which are present in widely differing proportions, or with other materials which have been absorbed by it and deposited in its substance.

THE CELL-CONTENTS.—Besides the protoplasm or living material present in the cell, very many other substances are found there which are extremely variable in nature and amount. All these are to be associated in some way with the vital activity of the protoplasm. As the latter is practically stationary in the cell and carries on its life-work there, it is evident that the substances necessary for its nutrition must be brought to it; and as these can pass readily from cell to cell only by means of the water which saturates the living parts, they must be in solution. The water which is always present in the cell is known as the *cell-sap*. It may be equally distributed through the protoplasm, as in young cells, or it may occupy as well the spaces in the latter which we have already described as vacuoles. It is never present as pure water, but always has various chemical substances dissolved in it. Besides containing the inorganic substances absorbed from outside, it also has in solution in it many bodies which have been made by the activity of the protoplasm; and as the processes carried out by the latter vary greatly in different cells, the cell-sap has no constant composition, but is affected in different cases by the nature of the work the cells do.

The substances which the protoplasm constructs are again destined to different purposes. Some are to be used up in various ways, either in the cell in which they are formed, or in other cells to which they are to be transported. These are generally known as *reserve* materials. They may remain in the cells for a longer or shorter period. Others are to be regarded as material which is of no further use to the plant at all, and are therefore to be got rid of. It is important to remember that the plant, unlike the animal organism, has little or no power to excrete anything from its body. Waste products, therefore, instead of being thrown off at once by definite channels, are usually packed away in particular cells of the plant—for instance, in the bark of trees.

Other products are neither reserve nor waste materials, but are formed in the cells to perform definite work there; such are the bodies known as *enzymes* or *ferments*, which carry out many chemical changes in the substances deposited in the cells.

As we have seen, many of these various bodies exist in the cell-sap in a state of solution; others, however, are deposited in a solid form. We can explain the presence of the latter in the same way as that of the others; they are either reserve or waste products, or charged with a definite duty in the work of the cell.

The cell-contents, varying thus from place to place and from time to time, stand in a very different position from the protoplasm, which is constant in its presence during the time the cell is living. The protoplasm carries out the vital work, aided by the various plastids already alluded to, when these are present. The other cell-contents are to be regarded only as aiding or resulting from the work of the protoplasm or the plastids.

The bodies included in the cell-contents, using the term in this restricted sense, may be divided into two groups: those soluble and those insoluble in the cell-sap. Among the former are included constructive materials for the protoplasm, such as freshly absorbed inorganic salts, and more highly elaborated bodies destined either for immediate use, or temporary storage, or possibly merely on their way through the cell. Various carbohydrates, chiefly sugars, vegetable acids and their salts, nitrogen-containing bodies in the form of amino-acids, belong to this category. Other substances, possibly nutritive, possibly only the by-products of nutrition, such as tannin, various glucosides, alkaloids, and other complex bodies, are also to be met with. In many cells, though with a more restricted distribution, we find various colouring matters in solution, chiefly blues, violets, or reds.

The bodies which form the second or insoluble group include starch grains, fats, proteid reserve materials, either in amorphous, granular, or crystalline form, and crystals of inorganic salts.

All these call for separate description.

Starch Grains.—Starch is not only widely distributed through the different parts of a plant, but it also occurs in varying quantity in all classes of plants with the exception of the Fungi. In all cases starch is a transitory product stored up for future use. When required for the nutrition of the plant, it is converted into sugar, which is a soluble substance, and can therefore be at once applied to the purposes of nutrition, which is not the case with starch in its unaltered condition, as it is then insoluble.

FIG. 643.

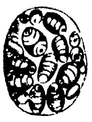


FIG. 644.

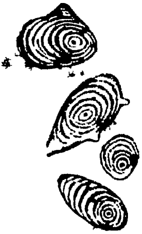


FIG. 645.

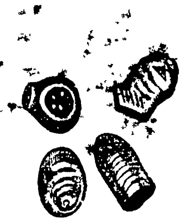


Fig. 643. Cell of the Potato containing starch granules.——*Fig.* 644. West-India Arrowroot (× 250).——*Fig.* 645. Sago meal (× 250).

When fully-formed starch is found floating in the cell-sap, it is in the form of colourless granules or grains (*fig.* 643), which are either distinct from one another, or more or less combined so as to form compound granules (*figs.* 649 and 652).

In form the separate granules are always spherical or nearly so in their earliest condition. In some cases this shape is nearly maintained in their mature state, as in Wheat starch (*fig.* 650), but the granules frequently assume other forms, becoming ovate, elliptical, more or less irregular, club-shaped, or angular (*figs.* 644–647 and 651). Starch granules vary extremely in size in different plants, and even in the same cell of any particular plant. The largest granules known appear to be those of Canna starch, or, as it is commonly termed, 'Tous-les-mois,' where they are sometimes as much as the $\frac{1}{250}$ of an inch in length (*fig.* 647); while the smallest granules, among which may be mentioned those of Rice starch (*fig.* 651), are frequently under $\frac{1}{5000}$ of an inch in length.

Starch first makes its appearance as minute colourless granules in the interior of the chlorophyll grains when exposed to sunlight. These primary starch granules rarely grow to any considerable size. In the parts of the plant which are not exposed to light, grains of larger dimensions and of some complexity of structure are met with. These are formed by the activity of another form of plastid, much like the chloroplast, but, on account of the absence of the green colour, known as a leucoplast or amyloplast (*fig.* 646). In a grain formed by such a leucoplast (*figs.* 647 and 648), we may observe a roundish dark spot, which is termed the *hilum*, situated near one end of the granule; and surrounding this a variable number of faint lines which alternate with other darker ones, so that the whole presents the appearance of a series of more or less irregular concentric shells placed around a common point. The cause of these appearances has given rise to much discussion; but from the observations of Schimper and others there appears to be no doubt that these shells are separate layers of starch substance

FIG. 646.

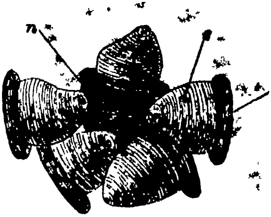


FIG. 647.

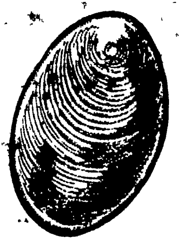


FIG. 648.

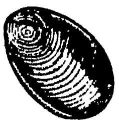


Fig. 646. Group of rod-like leucoplastids, *l*, each bearing a starch grain, *s*, collected round the nucleus, *n*, of a cell of the pseudo-bulb of an Orchid (*Phajus grandifolius*). × 500. After Schimper.——*Fig.* 647. Tous-les-mois (× 250).——*Fig.* 648. Potato starch (× 250).

that have been deposited successively by the amyloplast round the first formed portion, which is therefore more or less central. The various shapes of starch grains are due to irregular deposition of these layers. If the grain is formed regularly in the interior of the amyloplast, the layers are concentric; if the formation commences towards some portion of its exterior and quickly bulges outwards, the layers are irregular, being thicker and more numerous on the end of the grain which is nearest to the bulk of the plastid, as in the Potato (*fig.* 648). Probably the grain is always covered by the substance of the plastid, though there may be only a very delicate film-like layer of the latter over the protruding portion of the starch grain.

Compound starch grains are frequently met with. These are of two kinds; some are due to two or more grains having been pressed together during their development. Such grains usually originate by two or more arising symmetrically in the interior of the same plastid. Others are found to contain two or more hila, each with its concentric rings, and the whole surrounded by several layers of the same material. In this case the amyloplast has begun to form two or more grains at points towards its exterior, and these in time have come into contact. The further activity of the plastid has led to the aggregation becoming surrounded by deposits or shells of starch (*fig.* 652, B).

FIG. 649.

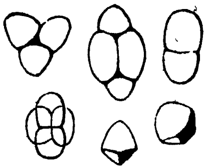


FIG. 650.

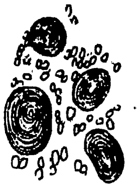


FIG. 651.

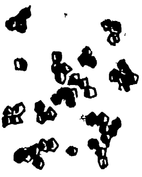


Fig. 649. Compound starch granules of West-India Arrowroot. After Schleiden. *Fig.* 650. Wheat starch (× 250).——*Fig.* 651. Rice starch (× 250).

In some cases the starch grains are of extremely curious shape. They may be linear, or like dumb-bells with elongated handles, as in *Euphorbia* (*fig.* 653). The latter are formed by plastids which are more active at their extremities than along the intermediate portion.

In many cells the starch grains are extremely minute and occur in enormous numbers, as in the style of the Lily. These specks are probably formed directly by the protoplasm, as no plastids have yet been discovered in the cells of this tissue.

The starch granule consists of the true *starch-compound* and *water*. The starch-compound is composed of two substances, which are intimately blended together, viz. *granulose* and *starch-cellulose*. The granulose makes up by far the greater part of the starch-compound; it is capable of being dissolved out of the cellulose by saliva and dilute acids, and it is to it that the starch granule owes the violet-blue colour which it assumes when treated with a solution of iodine. The cellulose on the other hand, not being soluble, is left behind as a skeleton, and is not coloured blue by the iodine solution.

Fig. 652.

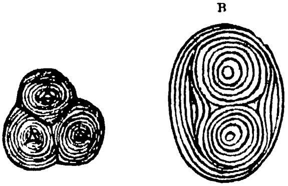


Fig. 653.

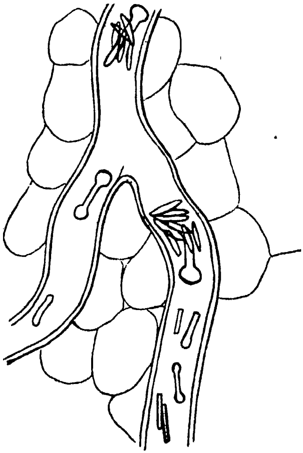


Fig. 652. A. Compound ; B. Semi-compound granule of starch.——*Fig.* 653. Part of a laticiferous cell from *Euphorbia splendens*; it contains starch granules of a peculiar dumb-bell and somewhat rod- and bone-like form.

Starch is insoluble in cold water, alcohol, ether, and oils. By the action of boiling water it swells up and forms a mucilage or paste; if when cooled iodine be added to this, a deep blue colour is produced; this colour disappears on heating the mixture, returning, however, as it cools. The starch grain gives the same reaction with iodine as the solution. If starch be exposed to a temperature of about 320° F. for a short time, it is converted into a soluble gummy substance, called *dextrin* or *British gum*. By the action of dilute sulphuric acid it is converted into sugar. The same change is brought about in the cells of the plant by a peculiar nitrogenous body known as *diastase*, a member of a group of bodies termed *enzymes*, which are of widespread occurrence in plants and which will be spoken of later. Starch affects polarised light in a somewhat similar manner to cellulose.

Proteids.—We have already seen that the protoplasm of the cell encloses in its meshwork varying quantities of the peculiar nitrogenous material known as proteid. In some cells this exists in large proportion in amorphous form. In many cases, however, it is deposited in the form of grains of definite shape and sometimes of complex character. These grains are known as *aleurone grains*. They consist of mixtures of proteids belonging to the globulin and albumose classes, which show considerable differences in solubility. In most cases they can be seen to lie in a coarse meshwork of protoplasm. They are especially characteristic of the cells of the interior of the seed.

FIG. 654.

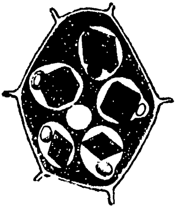


FIG. 655.

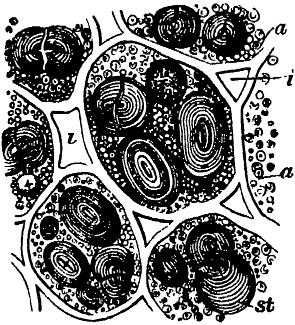


Fig. 654. Cell from the endosperm or albumen of the seed of the Castor-oil plant (*Ricinus communis*) in dilute glycerine, showing large transparent proteid or aleurone grains, with crystalloids and globoids embedded in them. After Sachs.——*Fig.* 655. Cells of a very thin section through a cotyledon of the embryo in a ripe seed of the common Pea (*Pisum sativum*). *a*, *a*. Aleurone grains. *st*. Starch granules. *i*, *i*. Intercellular spaces. After Sachs.

The aleurone grains vary very much in size and shape. In the Pea they may be seen as very small round bodies lying in the same cells as starch grains (*fig.* 655). In the Lupin they are larger, and occur in conjunction with oil, but not starch. In both these cases they show no structure. In the Castor-oil seed and in that of the Brazil nut they differ from the simple forms described. The larger part of the aleurone grain is occupied by a crystalline portion, known as the *crystalloid*. This, like the grain itself, is proteid in character. There is present also in these grains a rounded aggregation of mineral matter, a double phosphate of calcium and magnesium, which is termed the *globoid* (*fig.* 654).

In a few cases cells are found to contain crystalloids of proteid not included in an aleurone grain. Such bodies occur frequently in certain parts of the tuber of the Potato, and in some Seaweeds.

Fats and Oils.—Certain cells, generally in the fruit or seed, contain fats or oils saturating the protoplasm, or sometimes occupying nearly the whole of the cell-cavity. Ethereal oils are found similarly in cells of various parts of the leaves or stems, usually in small aggregations of cells in the interior of the tissue, or in cells of the hairs which grow from the epidermis. These are generally spoken of as oil-glands, or glandular hairs.

Resins.—In certain plants, particularly those belonging to the natural order *Coniferæ*, certain aggregations of cells are found to contain quantities of peculiar material, generally termed *resin*. This material is different in composition in different plants; it may be recognised by its staining red with alcoholic tincture of alkannin. It is soluble in alcohol, benzol, and ether, but insoluble in any watery fluid.

Raphides.—This name is now very generally applied to all inorganic crystals of whatever form which are found in the cells of plants, although the term *raphides* was originally given to those only that had the form of needles (*figs.* 658 and 659). Raphides may be found more or less in nearly all orders of plants, and in all their organs; generally, however, they are most abundant in the stems of herbaceous plants, in the bark of woody plants, and in leaves and roots. In some plants they occur in such enormous quantities that they exceed in weight the dried tissue in which they are deposited: this may be especially observed in some members of the *Cactaceæ*. The raphides are usually contained in cells from which starch, chlorophyll, and other granular structures are absent (*fig.* 658), although this is by no means necessarily the case.

The raphides may occur singly in the cells, as in those of the bark of the Locust tree (*fig.* 656); but far more commonly there is a number of crystals in the same cell. In the latter case they are usually placed either side by side, as in the stem of *Rumex* (*fig.* 658); or in groups radiating from a common point, and so assuming a clustered or conglomerate appearance, as in the stem of the common Beet (*fig.* 657). The former have been termed *acicular raphides*, and the latter *conglomerate raphides* or *sphæraphides.*

In the common Arum, where raphides are very abundant, and in some other *Araceæ* the cells which contain the raphides are filled with a mucilaginous sap; when they are moistened with water the sap absorbs it freely, so that they are distended and caused ultimately to burst and discharge their crystals from an orifice at each end (*fig.* 659).

FIG. 656.

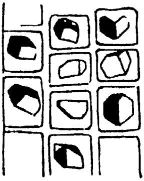


FIG. 657.

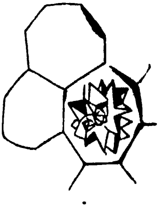


FIG. 658.

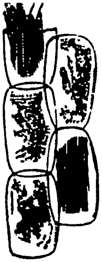


FIG. 659.

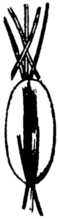


Fig. 656. Solitary crystals in the cells of the bark of the Locust tree. After Gray.——*Fig.* 657. Conglomerate raphides or sphæraphides of the Beet. *Fig.* 658. Acicular or true raphides of a species of *Rumex*. Two cells contain raphides, and three of them chlorophyll granules.——*Fig.* 659. True or acicular raphides of an Arum being discharged through endosmose under the influence of water.

The crystals thus described consist generally of calcium oxalate, which crystallises in two forms according to the proportion of water it contains. When the crystals contain six equivalents of water of crystallisation, they form octahedra (*fig.* 657), as in the conglomerate raphides or sphæraphides; when, on the other hand, there are only two equivalents of water of crystallisation, bundles of acicular crystals or true raphides are produced (*figs.* 658 and 659). In rarer cases the crystals are composed of calcium carbonate.

The raphides are usually regarded as waste products, or byeproducts of the metabolism of the cell. They are frequently surrounded by a delicate pellicle of cellulose, thus being shut off from contact with the protoplasm.

Of the substances which are met with in solution in the cell-sap, little more need be said at present. The kinds of sugar found are chiefly maltose, grape sugar, and cane sugar. A peculiar carbohydrate body, *inulin*, is found in the tubers or tuberous roots of certain of the *Compositæ*, particularly the Dahlia and the Artichoke. This substance has the same percentage composition as starch, and, like the latter, is readily convertible into a form of sugar. It can be made to separate out from the cell-sap by keeping the tissue containing it in spirit. A section taken through such a piece of tissue and mounted in water will show large sphæro-crystals of inulin, often extending through several contiguous cells (*fig.* 660).

FIG. 660.

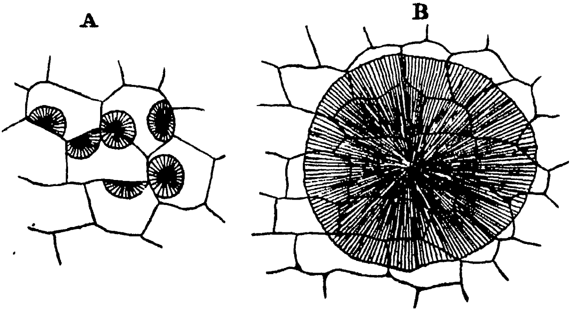


Fig. 660. Sphæro-crystals of inulin from the Artichoke. A. Small crystals in interior of cells. B. Large crystals extending through many cells. (× 250)

The amino-acids, such as asparagin, leucin, &c., which are found in the cell-sap, are generally the result of the decomposition of proteid material. They are very prominent in young seedlings and in germinating seeds.

In many cells the peculiar bodies spoken of as enzymes occur. These are very varied, and a discussion of their peculiarities must be deferred to a later section of this work. They can only be detected in cells by the results of their activity.

The cells vary much in size in different plants, and in different parts of the same plant. Polygonal or oblong cells, on an average, vary from about $\frac{1}{250}$ to $\frac{1}{1200}$ of an inch in diameter; others again are not more than $\frac{1}{5000}$; while in some cases they are so large as to be visible to the naked eye, being as much as $\frac{1}{50}$ or even $\frac{1}{30}$ of an inch in diameter. The largest occur in the pith of plants, in succulent parts, and in aquatic plants.

The dimensions of elongated cells generally afford a striking contrast to those of polygonal ones; for while we find that their transverse diameter is commonly much less, averaging about $\frac{1}{1500}$ of an inch, and frequently not more than $\frac{1}{3000}$, they become much more extended longitudinally, sometimes reaching four, five, or more inches in length. More generally, however, they vary from about $\frac{1}{40}$ to $\frac{1}{12}$ of an inch in length.

Those cells again which have an unrestrained development are frequently also far more extended in length. The cell of which each filament of cotton is formed is sometimes as much as one or two inches long. On the other hand, some of the minute cells known as *microbes* or *micro-organisms* are not more than $\frac{1}{25000}$ of an inch in diameter.

CHAPTER II.

FORMATION OF CELLS—TISSUES.

We have seen that every plant commences its life as a single cell, sometimes a naked piece of protoplasm, as a gamete, or one clothed with a cell-wall, as most kinds of spore. It follows from this that all the cells of which the most complex plant body is composed are derived from one of these by some process of multiplication. In this, as in all other vital processes, the protoplasm is the active agent. In the production of the gamete or spore itself we have to do with the formation of a new cell, generally but not necessarily by a process of multiplication; while in the case of all zygospores and oospores the new individual is the result of fusion of cells, and therefore involves diminution instead of increase of number.

We may distinguish several different methods of cell formation, which can, however, be classed under the two heads mentioned above. First we will take those cases in which the new cell results from the division of an antecedent cell, and afterwards those in which no such division takes place.

1. Formation of New Cells by Division of Antecedent Cells.—This is by far the most frequent method. Usually a cell divides into two, and a wall is immediately formed between them. Less often a variable number of cells is formed in the interior of a cell, known generally as the *mother-cell*, and they become clothed with cell-walls simultaneously or not at all. The former is most common in vegetative, the latter in reproductive processes. The two processes are termed *cell-division* and *free cell-formation.*

Cell-division.—We have pointed out that the division of the cell is brought about by the protoplasm. The actual division is preceded by a division of the nucleus, which is known as *karyokinesis*, or *indirect nuclear division.*

In the cases that have been most completely investigated the nucleus consists essentially of a delicate network of fibrils of chromatin, embedded in a hyaline substance, and surrounded by a more or less well-defined outline derived from the cell protoplasm and known as the nuclear membrane. Associated with it in some cases are two small centrospheres. Karyokinesis begins by the network of fibrils becoming coarser and gradually separating to form a long coiled fibre. The nucleoli disappear, and the nuclear membrane can no longer be distinguished. At the same time, in those cases in which centrospheres have been seen, they shift their position and come to lie on opposite sides of the nucleus at some little distance from it. The long coiled fibre of chromatin breaks up into a number of pieces, often V-shaped, which point towards the centre of the nucleus. The number of these varies in different cells, but is constant in those of the same tissue. These pieces of the fibre are known as *chromosomes*. The chromatin in the fibres is broken up into thin discs, which are separated from each other by smaller discs of unstainable substance. Threads of delicate character may next be seen to extend from one centrosphere to the other, forming a body known as the *nuclear spindle*. The ends of the spindle are known as the poles of the nucleus. The nuclear fibrils, or chromosomes, travel along these threads, with which their points are in contact, till they form a plate across the spindle. This stage is constant in all cases of karyokinesis, though the details of its formation vary in different cases. The body is sometimes called the *equatorial plate* (*fig.* 661, *b*). After this stage is reached, each chromosome splits longitudinally into two, and the equatorial plate divides into two in such a way that half of each chromosome points its base to one

FIG. 661.

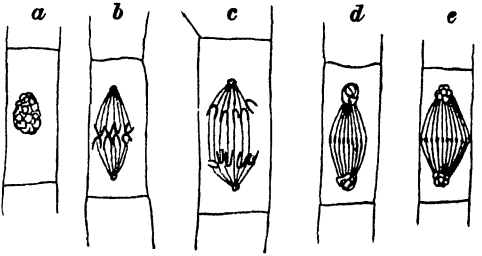


Fig. 661. Stages in karyokinetic division of the nucleus. *a.* Resting nucleus. *b.* Stage of equatorial plate. *c.* Separation of the chromosomes. *d.* Commencement of formation of cell-wall. *e.* Extension of nuclear spindle across the cell.

centrosphere or pole, and the other half to the other. The two sets of fibrils so formed then separate and travel back along the spindle fibres towards the two poles of the nucleus, changing their positions as they go till their convex sides point towards them. They thus collect into two places which are determined by the position of the poles of the nucleus (or the centrospheres if the latter are present), and present there the appearance of two somewhat star-shaped aggregations. This is known as the *diaster* stage. The chromosomes at each pole now become united by their ends, and the fibres so formed become closely coiled, thus constituting two new nuclei, each gradually becoming well defined by the appearance of a nuclear membrane; the original appearance is thus regained, nucleoli appearing in each new nucleus. The spindle fibres may remain connecting the new nuclei for a time, as is the case when a cell-wall is formed immediately; or they may disappear at once. In the cases in which a centrosphere has been observed it divides at this stage, and the two new centrospheres may be distinguished in contact with some point of the new nucleus.

FIG. 662.

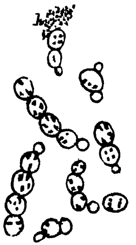


FIG. 663.

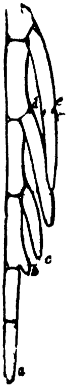


Fig. 662. Yeast plant in process of development.——*Fig.* 663. *Conferva glomerata*, showing the progressive stages of gemmation or budding (*b*, *c*, *d*, *e*). *a*. Terminal cell. After Von Mohl.

In ordinary cell-division the formation of the new nuclei is followed by the appearance of a cell-wall in the original position of the equatorial plate. If the spindle fibres do not stretch completely across the cell, others are formed beside the original ones, till the spindle is in contact with the lateral cell-walls. Granules which have been floating in the cell-protoplasm are to be seen streaming along the spindle fibres till they form a plate stretching across the middle of the cell from wall to wall. From this cell-plate the septum of cellulose is formed. The central portion of the plate may be formed before the extension of the spindle across the cell is complete.

A variation of this process is seen in the formation of the spores of certain plants; for instance, the microspores of Dicotyledons. The original nucleus of the mother-cell of the spores divides into two as described above. The spindles disappear, and each nucleus divides again. New spindles are next formed between the four nuclei (*fig.* 664, B), and then cell-plates or cell-walls are simultaneously developed between them, giving rise to four so-called *special mother-cells*, each of which develops a spore. The division of the protoplasm in this case is often preceded by a thickening of the cell-wall at the places to which the new septa will be attached, so that the protoplasm is partially separated before the new walls appear.

FIG. 664.

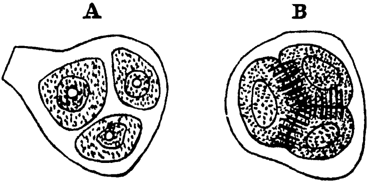


Fig. 664. *Helleborus fœtidus.* After Strasburger. (×540) Quadripartition of mother-cell of pollen: in B the connecting threads and cell-plates are shown; in A the walls have been formed. Only three are visible, the fourth not being in focus; the mode of development is tetrahedral.

In certain of the lower Algæ, after the division of the nucleus and separation of the daughter nuclei, the formation of a new cell-wall between them is effected by an ingrowth from the wall of the mother-cell, which gradually extends inwards across the cavity.

In ordinary cell-division the two cells are usually of the same size. In some cases a variation in this respect is seen, as in the cells of the Yeast plant. These often put out a lateral protuberance of smaller size, which is gradually cut off by the constriction of the cell-wall between the two. This variation is known as *budding*, or *gemmation* (*fig.* 662). It is not uncommon among the lower Thallophytes.

In a few cases in some of the lower plants the division of the cell is not preceded by division of the nucleus. In others, after the nucleus has divided, the new cell-wall is formed by an ingrowth from the walls of the original cell.

Free Cell-formation.—In this method of cell-formation the nucleus divides into two, each of those into two, each again into two, the process continuing till a number of nuclei are formed.

The protoplasm aggregates round each nucleus, and a number of naked cells are so formed in the interior of the original cell. In some cases, as in the formation of the zoogonidia and gametes of many Algæ and Fungi (*fig.* 665), they remain naked and are discharged in this condition from the cell in which they are formed. In other cases, each new cell secretes a cell-wall round itself.

In its simplest form, this mode of cell-production results in the formation of a number of isolated cells (*fig.* 665). In certain cases, however, the cells are combined into a tissue, as in the endosperm of Phanerogams. When this takes place, the nuclei become arranged in a single layer over the internal surface of the megaspore; protoplasm aggregates round each nucleus, and a common cell-wall is formed between each two adjacent cells, separating them from each other. Their surface which is towards the cavity of the megaspore remains for a little while naked, but soon they secrete each for itself a cell-wall over it, thus forming a peripheral layer of closed cells round the cavity of the megaspore. Further multiplication of the cells takes place by repeated cell-divisions till a mass of tissue fills the spore.

FIG. 665.

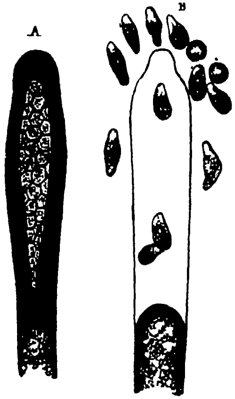


FIG. 666.

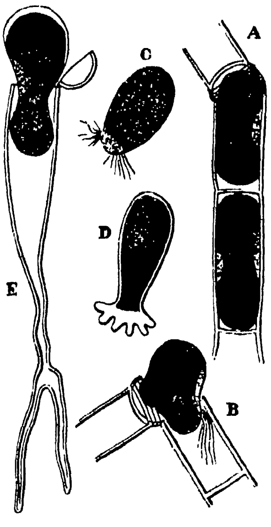


Fig. 665. Formation of zoogonidia in *Achlya*. A. Zoogonidangium, still closed. B. The same burst, with the discharged zoogonidia. After Carpenter.——*Fig.* 666. A, B. Escape of the swarm-spores of an *Œdogonium*. C. One in free motion. D. The same after it has become fixed, and has formed the attaching disc. E. Escape of the whole protoplasm of a germ-plant of *Œdogonium* in the form of a swarm-spore. After Pringsheim.

The formation of the special mother-cells of the spores, described above as a variation of cell-division, is often included under free cell-formation.

The principal difference between the two modes is that in free cell-formation the new cell, if clothed at all, is nearly or quite surrounded by a freshly secreted cell-wall; in cell-division a new wall is only formed across the line of the division.

2. **Formation of New Cells without Division.**—Two modes of cell-production belong to this category. The first is known as *rejuvenescence*, and is met with only in connection with reproductive cells. It consists in the protoplasm of a cell withdrawing itself from the cell-wall, and after a short period of quiescence secreting for itself a fresh membrane. It may remain within the original cell-wall, as in the formation of spores inside the special mother-cells, which have themselves been formed as above described by cell-division. On the other hand, it may be set free. In this case the cell-wall is not secreted by it until after its escape. It is, moreover, at first usually furnished with cilia, sometimes attached to one end as in the zoospores of *Œdogonium* (*fig.* 666, C), or over the whole surface as in the zoocœnocytes of *Vaucheria*.

Fig. 667.

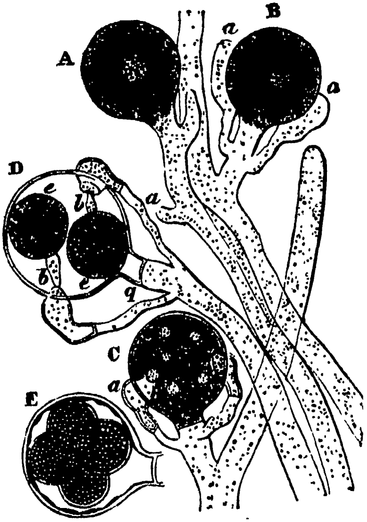


Fig. 667. Oogonia and antheridia of *Achlya lignicola*, showing cell-division. The letters A to E indicate the course of development. The protoplasm of a cell or branch of a cell collects into a globular form, A, B, and by the formation of a septum, D *q*, becomes an independent cell (the oogonium). The protoplasm then breaks up into two or more parts, D, *e*, *e* (oospheres), which quickly become spherical, and after possible fertilisation by the antheridia *a*, *a*, penetrating into the oogonium by their beaks, *b*, *b*, as seen in D, secrete a cell-wall E, and become oospores. After Sachs.

The other mode of cell-production without cell-division is that of the fusion of two cells to form a new one. Like the last-described method, it occurs only in connection with the processes of reproduction. It includes all the cases of the fusion of gametes already described. The cells taking part in the fusion are at the time naked cells, consisting of protoplasm and nucleus. They may be similar or dissimilar in size, may be set free from the cells in which they were formed, as in the case of the ciliated gametes of *Ulothrix* (*fig.* 609) or the spermatozoids of the higher Cryptogams, or may leave their parent cell only to pass into that of another gamete, as in *Spirogyra* (*fig.* 486) and possibly in *Achlya* (*fig.* 667), or may remain always in the cell in which they are developed, as is generally the case with oospheres. When the fusion takes place, protoplasm unites with protoplasm, nucleus with nucleus, &c., and a new cell results which clothes itself with a cell-wall, and becomes a new individual. The process of fusion of dissimilar cells is generally called *fertilisation*; that of union of similar cells is known as *conjugation*. The new cell formed by the fusion is a *zygote*; in the first case it is sometimes called an *oospore*, in the second, a *zygospore*.

FIG. 668.

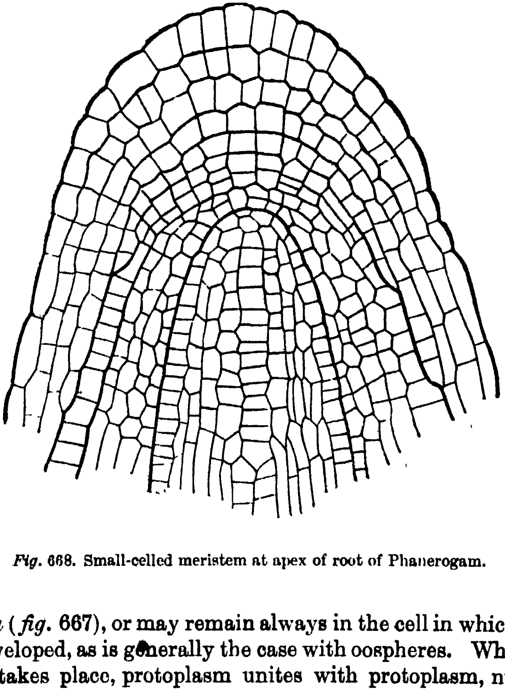


Fig. 668. Small-celled meristem at apex of root of Phanerogam.

The Tissues.

By one or other of the vegetative methods of cell-production described, the original unicellular plant becomes a multicellular body, and its ultimate form may be that of a row of cells forming a filament, or a flat plate, one or a few cells thick, or, again, a mass of cells of very variable size and shape. We have seen that in such a mass different cells or aggregations of cells are specially set apart to discharge particular duties. Such collections of cells are called *tissues.* We speak of the tissues of nutrition, the protective tissues, and so on. The cells which compose such a tissue commonly resemble each other more closely than they do other cells, and are said to obey a common law of growth. They originate generally by division of either a single cell, or of the cells of a well-defined group or *meristem,* so that they are held to have a common origin. Only such collections of cells as fulfil these conditions are considered true tissues.

MERISMATIC TISSUE, OR MERISTEM.—In the development of the vegetative body of the plant, the new cells are produced by cell-division. In some cases every cell as it is produced possesses and retains the power of division, so that the plant can increase throughout its whole length. This is commonly the case with filamentous plants such as *Spirogyra.* In most cases, however, the power of cell-division speedily becomes localised at certain parts of the plant body, which then carry out all further increase in length. Such points are called *growing points*: they are generally terminal, and the cells of which they are composed, which have the power of cell-division, are called *merismatic* cells. The individual cells do not long retain this power, but after a period of growth acquire various forms, and subsequently change but little during life, constituting *permanent* tissue. Finally they lose their protoplasm, and are no longer living.

There are two chief types of growing point which are found at the apices of the axis of the plant. In both, multiplication of cells leads to a continued forward advance of the apex, and the youngest cells are in the front of the mass, so that the growing point is nearly always more or less conical; two main lines of division of the cells can be seen, one parallel to the surface of the apex, or *periclinal*; the other at right angles to it, or *anticlinal.* The merismatic tissue is not of very great extent, and behind it the cells can be observed to be growing or increasing in size, and gradually changing into permanent tissue.

In the first type the cells which are thus dividing are all alike in appearance, and form a well-defined group which gradually becomes differentiated, as the cells get older, into various forms characteristic of different regions of the axis (*figs.* 668 and 670). This small-celled meristem is always found in Phanerogams and in some Cryptogams.

FIG. 669.

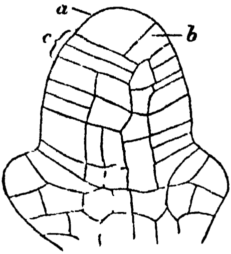


FIG. 670.

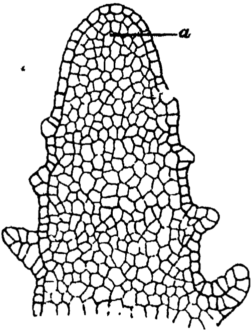
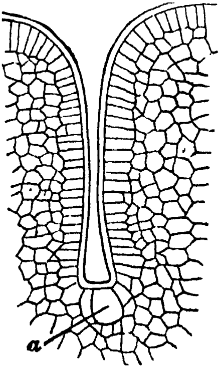


Fig. 669. Growing point of stem of *Equisetum*. *a*. Apical cell. *b*. *c*. Segments cut off from it.——*Fig*. 670. Growing point of stem of *Elodea*. *a*. Apical meristem. After Kny.——*Fig*. 671. Growing point of *Pelvetia*. *a*. Apical cell. After Kny.

FIG. 671.



The other type is marked by the presence at the apex of a single large, generally pyramidal, cell, the base of the pyramid being external (*fig.* 669). From this, successive segments are cut off parallel to each side in turn, the apical cell growing to its original size after each division. In stems there is no segment cut off from the external face, but this takes place in roots, so that the apical cell is never exposed in the latter case (*fig.* 769). The segments when cut off usually divide periclinally each into two; further divisions of each of the latter give rise to the mass of the tissue. Such a growing point may be conical or depressed, according to the amount of growth taking place in the inner or outer segments and the cells which arise from them (*figs.* 669 and 671).

This form of primary meristem, in which an apical cell is so prominent a feature, is chiefly characteristic of Cryptogams.

An intermediate form is met with in some of the Vascular Cryptogams in which a group of initial cells, frequently four in number, replaces the apical cell.

Besides these apical meristems, similar tissue occurs in other parts of the mass of the plant. These collections are chiefly connected with growth of the axis in thickness rather than in length, and will be treated of later in detail. The cells are either much like those of the small-celled meristem or are longer than broad. They exist in sheets or bands, usually one cell thick. They include the cambium and phellogens of stems and roots.

When cells are formed by cell-division in a growing point, the new cell-wall arises at right angles to the walls with which its edges are in contact. Hence at their first formation all such cells are cubical or nearly so. By growth in various directions, mutual pressure, &c., they change their shape and relative dimensions, giving rise to collections having very different appearances.

The cell-wall, at first thin and composed mainly of cellulose, thickens as already described, and becomes chemically altered, giving rise to still more complicated structures.

In the early changes that take place as permanent tissue is replacing meristem, the close contact of the cells becomes continually interrupted. During the changes of tension that occur in a growing mass of cells, cracks or fissures arise in the substance of the cell membranes, generally at the angles, and so small intercellular spaces are formed. The several spaces in a tissue extend till they communicate, and a system of intercellular channels is formed which extends throughout the plant, and contains air. The intercellular space system so formed is very prominent in certain parts, especially in leaves and in the stems of aquatic plants (*fig.* 749).

The changes that take place in the composition of the cell-wall usually affect the primary septum between the cells in a different way from the successive thickening layers. The original wall, though altered in many important respects, can generally be distinguished in the thickened wall of stratified cells, when it is known as the *middle lamella* (*fig.* 677, *m*).

Parenchyma.—A collection of cells, the individuals of which remain more or less of equal diameter in all directions, is known as *parenchyma*. The cells may remain with thin walls, or the latter may be thickened equally or unequally, giving rise to various modifications, of which the following are the more important:—

a. Round or Oval Parenchyma (*fig.* 672).—This is formed of rounded or more or less oval cells, with small spaces between them. It is most prominent in succulent plants. It is connected by various transitional forms with—

b. Stellate Parenchyma, which consists of stellate cells (*figs.* 620 and 673), or cells with an irregular outline produced by projecting rays, and in contact only by the extremities of such rays, so as to leave large irregular spaces between them.

FIG. 672.

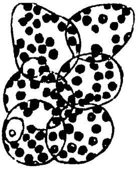


FIG. 673.

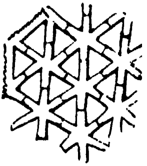


FIG. 674.

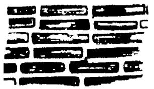


FIG. 675.

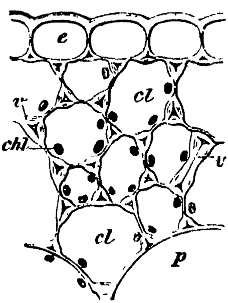


Fig. 672. Round or oval parenchyma. In two of the cells a nucleus with a nucleolus may be seen.——*Fig.* 673. Stellate parenchyma, composed of stellate cells with three-cornered intercellular spaces.——*Fig.* 674. Muriform parenchyma.——*Fig.* 675. Transverse section of the petiole of a species of *Begonia*. *e.* Epidermis with cuticle above and hypoderma below, the latter formed of collenchymatous cells *cl*, *cl*, with thickened angles, *v*, *v*. *chl.* Chlorophyll granules. *p.* General parenchyma, below hypoderma. After Sachs.

c. Regular or Polyhedral Parenchyma.—This is formed of polyhedral cells, the faces of which are frequently nearly equal, and so combined as to leave very small interspaces. It is commonly found in the pith of plants.

d. Elongated Parenchyma.—This is composed of cells elongated in a longitudinal direction so as to become cylindrical. It occurs frequently in the stems of Monocotyledonous plants.

e. Tabular Parenchyma.—This consists of tabular, closely adherent cells. It is found in the epidermis and other peripheral parts of plants (*fig.* 675, *e*). A variety of this kind of parenchyma is called ***muriform***, because the cells of which it is composed resemble in their form and arrangement the courses of bricks in a wall (*fig.* 674): this variety occurs in the medullary rays of the stems of Dicotyledons and in corky formations.

Such are the commoner varieties of parenchyma, all of which are connected in various ways by transitional forms; but other special kinds also occur. In the tissue which lies below the epidermis of plants, and which has been termed the *hypoderma*, we sometimes find the parenchyma composed of cells which are especially thickened at their angles but never become lignified (*fig.* 675, *cl*, *cl*). This kind of parenchyma is called *collenchyma*. Another variety of the same kind is termed *sclerenchyma*: it consists of cells which have become much hardened by thickening layers and lignified, as in the stems of Palms. The cells of collenchyma and sclerenchyma are sometimes prosenchymatous.

FIG. 676. FIG. 677. FIG. 678. FIG. 679. FIG. 680. FIG. 681.

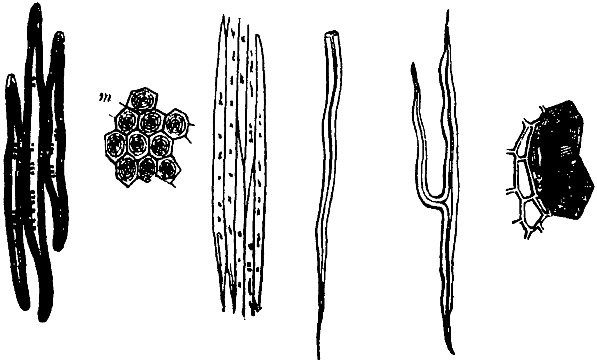


Fig. 676. Prosenchymatous wood cells.——*Fig.* 677. Transverse section of prosenchymatous cells, showing the thickness of their walls. *m.* Middle lamella.——*Fig.* 678. Prosenchymatous cells in combination.——*Fig.* 679. Upper end of a bast fibre.——*Fig.* 680. Branched fibre. After Schleiden. *Fig.* 681. Transverse section of fibres, showing the thickness of their walls.

In some of the lower orders of plants there is a peculiar kind of tissue present, to which the names of *Tela contexta* and *interlacing fibrilliform tissue* have been given. It occurs chiefly in the Fungi (*fig.* 623), and consists of very long thread-like cells, or strings of cells, simple or branched, with either thin, soft, readily destructible walls, or dry and firm ones, the whole inextricably interwoven or entangled with each other so as to form a loose fibrilliform tissue. This tissue, which is now usually known under the name of *hyphæ* or *hyphal tissue*, constitutes, as a general rule, the vegetative portion of all Fungi. In the larger Fungi the same tissue forms a more compact structure at certain parts, particularly on their surface, where it is arranged as a kind of skin, and in the stalks, which are frequently of some thickness. It then constitutes what is termed *pseudo-parenchyma.*

PROSENCHYMA.—Besides these collections of isodiametric cells we find others whose length greatly exceeds their other diameters. They are usually pointed in shape, their ends overlapping, or extending in between the ends of their immediate neighbours. These collections constitute what is known as *prosenchyma.* As in the case of parenchyma the walls of the cells, or *fibres*, are sometimes lignified, pitted, &c. Prosenchyma is largely present in woody tissues; it is not, however, confined to them, but may be found as isolated strands occupying various positions in the plant body. In some forms the fibres are branched (*fig.* 680). The cells of collenchyma and sclerenchyma are frequently fibrous.

The secondary wood of the *Coniferæ* (*fig.* 638) is entirely composed of prosenchymatous tissue, the constituent cells of which, fibrous in form, are known as *tracheïds.* They are marked by the peculiar bordered pits already described. These may be regarded as intermediate between prosenchyma and the vascular tissue described below.

VASCULAR TISSUE.—A further modification of the arrangement of cells is found in plants, constituting what is known as *vascular tissue.* The cells of this tissue are frequently fused together, the end walls between them becoming absorbed to a greater or less extent. A row of cells whose separating walls have thus disappeared is known as a *vessel.* Vascular tissue includes two forms, *tracheal tissue* and *sieve tissue.*

FIG. 682.

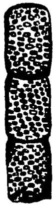


FIG. 683.

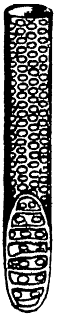


Fig. 682. Beaded pitted vessel.——*Fig.* 683. Pitted tracheïd terminating obliquely, and showing that the partition wall has been incompletely absorbed.

Tracheal Tissue.—This is usually composed of lignified cells which are placed end to end, forming columns, and which have lost their protoplasm. They are pitted in the various manners already described, forming spiral, annular, scalariform, or reticulated vessels (*fig.* 682). When the end walls are completely absorbed they form true vessels or *tracheæ.* The absorption is not always complete; indeed, in some cases columns of such thickened cells are found where the end walls persist, and are thickened in the same way as the lateral ones (*fig.* 683). The individual cells are then known as *tracheïds.*

Tracheïds occur in other forms than as the cells of a column; in certain orchids they constitute a somewhat parenchymatous-looking tissue in the sheath of the aerial roots. They are always lignified and usually pitted. There is no very sharp distinction between a fibre and a tracheïd when the latter does not appear as a segment of a vessel. The peculiar fibres with bordered pits, occurring in the secondary wood of the *Coniferæ*, are generally included under this term.

FIG. 684.

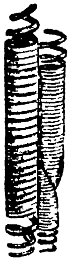


FIG. 685.

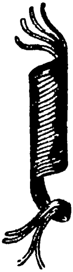


FIG. 686.

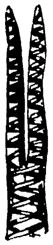


FIG. 687.

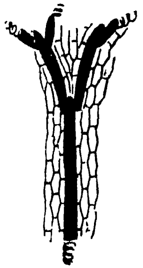


Fig. 684. Simple spiral vessels.——*Fig.* 685. Compound spiral vessel.——*Fig.* 686. Branched spiral vessel.——*Fig.* 687. Union of spiral vessels in an oblique manner.

The chief forms of tracheal tissue, whether composed of tracheïds or true vessels, may now be separately considered.

a. Pitted or Dotted Vessels.—A pitted vessel is formed from a row of cylindrical pitted cells placed end to end (*fig.* 682), by the absorption of the separating walls. Its mode of origin is clearly shown in many instances by the constrictions which its sides exhibit at various intervals (*fig.* 682); for these constrictions evidently correspond to the points where the component cells came in contact.

It sometimes happens that when a pitted or other vessel has lost its fluid contents, the neighbouring parenchymatous cells protrude through the pores which exist in its wall, and then multiply in its interior by division, forming a cellular mass which may completely fill it; to this intra-cellular tissue the name of *tüllen* or *thyloses* has been given. It may be well observed in the wood of the Oak, in that of *Robinia Pseudacacia*, in *Periploca*, and in the stem of *Cucumis sativus*.

b. Spiral Vessels.—This name is applied to vessels with tapering extremities, having the thickening matter of its walls disposed as either one continuous spiral fibril running internally round it from end to end, as is commonly the case (*fig.* 684), or two or more fibrils (*fig.* 685) running parallel to one another. Such vessels are often met with in the stem of the Banana and other allied plants, in the young shoots of the Asparagus, and in the Pitcher Plant. The fibril contained within the spiral vessel is generally so elastic as to admit of being detached from the wall and uncoiled when the vessel is pulled asunder. This appearance may be commonly seen by the naked eye by partially breaking the young shoots, flower-stalks, or leaf-stalks of almost any plant, or the leaves of the Hyacinth, Banana, and others, and gently pulling asunder the two ends, when the uncoiled fibrils appear like a fine cobweb. In most cases the coils of the fibrils are close together, so that the enclosing membrane cannot be observed between them; but in other instances they are more or less separated by portions of membrane (*fig.* 686).

FIG. 688.

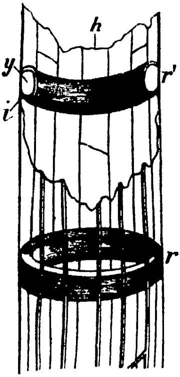


FIG. 689.

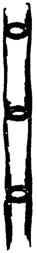


FIG. 690.

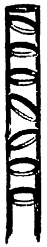


FIG. 691.

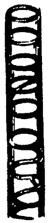


Fig. 688. Piece of an annular vessel from *Zea Mays*. *h*. The thin cell-wall; *r*, the annular thickening of the cell-wall; *r'*, vertical section of one of the rings, showing *y*, the inner substance, and *i*, the denser layer over the inner side of the ring projecting into the cavity of the cell. After Sachs.——*Figs.* 689, 690. Annular vessels.——*Fig.* 691. Vessel showing a combination of rings and spiral fibres.

Spiral vessels occur in the earliest differentiated portions of the wood of vascular bundles. In size they vary from $\frac{1}{300}$ to $\frac{1}{3000}$ of an inch in diameter. The average size is about $\frac{1}{1000}$ inch.

c. Annular Vessels.—In these vessels the thickening matter is arranged in the form of rings more or less regularly disposed upon their inner surface (*figs.* 688, *r*; 689, and 690). Sometimes the whole of the vessel presents this ringed appearance (*figs.* 689 and 690), while in other vessels we find two rings connected by one or more turns of a spiral, the two forms irregularly alternating with each other (*fig.* 691). In size they vary from about $\frac{1}{400}$ to $\frac{1}{800}$ of an inch in diameter. Annular vessels occur especially in the fibro-vascular bundles of the stems of soft, rapidly growing herbaceous plants.

d. Reticulated Vessels.—In these vessels the convolutions are more or less irregular, and connected in various ways by cross or oblique bands, so as to produce a branched or netted appearance (*fig.* 692).

FIG. 692.

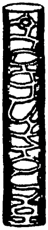


FIG. 693.

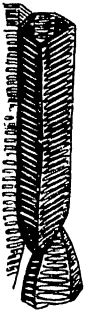


FIG. 694.

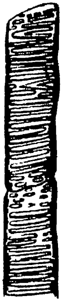


Fig. 692. Reticulated vessel.——*Fig.* 693. Prismatic scalariform vessels of a Fern.——*Fig.* 694. Cylindrical scalariform vessels of the Vine.

e. Scalariform Vessels.—The peculiar appearance of these vessels is owing to their walls being marked by elongated transverse pits or lines, arranged over one another like the steps of a ladder, whence their name (*figs.* 693 and 694). They are sometimes cylindrical tubes like the other vessels, as in the Vine (*fig.* 694), and in many other Dicotyledons, in which condition they resemble modifications of reticulated vessels; but in their more perfect state, scalariform vessels assume a prismatic form, as in Ferns (*fig.* 693).

The scalariform markings are often caused in the same way as those of bordered pits, the thin places, instead of being small and circular, being broad and extending quite across the side of the cell.

The *annular*, *reticulated*, and *scalariform vessels* have commonly tapering points like the spiral vessels, and thus overlap at their extremities when they come in contact (*fig.* 693). But in other instances they terminate more or less obliquely, or by flattened ends, like most pitted vessels.

Sieve Tissue.—This is generally associated with some form of tracheal tissue in certain strands of tissue known as vascular bundles. It occasionally exists as isolated columns in the pith or cortex of stems. In young roots it is found in independent strands, side by side with similar strands of tracheal tissue. The cells of which it is composed are thin-walled and never lignified. Two kinds of cell are found in it in the most highly developed forms, the sieve tube proper and its companion cells. The sieve tube is composed of a number of cells or segments placed end to end (*fig.* 695). The separating wall is seldom much thickened, but has deposited upon it on both sides a peculiar material known as *callus*, probably a modification of the original material of the wall. The separating wall generally forms a *sieve plate*, being perforated by a number of apertures, which are lined by the callus deposit, and through which the contents of

FIG. 695.

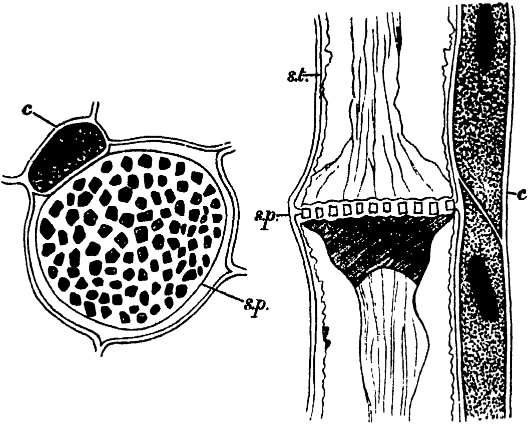


Fig. 695. Sieve tubes and companion cells from the stem of *Cucurbita*, in transverse and longitudinal section. *s.t.* Sieve tube. *s.p.* Sieve plate. *c.* Companion cells. × 540. After Strasburger.

the two segments communicate. The protoplasm of the sieve tube is considerably changed, being, with the exception of a lining layer, transformed into a slimy material which is especially conspicuous in the neighbourhood of the sieve plate. The adult tube contains no nucleus.

The companion cells are so called because they are cut off from the sieve-tube segments at the time of their first appearance. They are smaller in diameter than the tube itself, and contain protoplasm and nuclei (*fig.* 695, *c*).

In the Angiosperms the sieve plates at the end of summer become blocked up by an addition to the callus, and remain closed during the winter, communication being re-established in the spring.

FIG. 696.

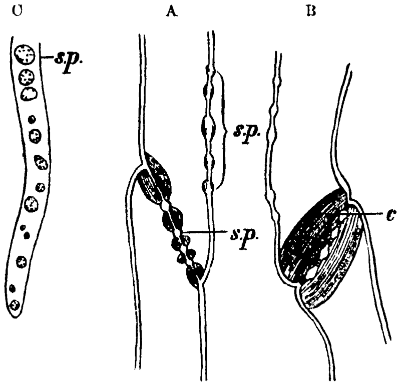


Fig. 696. Sieve tubes of *Rhamnus purshiana*. A, B. Middle portion of a tube, showing section of sieve plates, *s.p.* *c.* Callus deposit on a sieve plate. C. Termination of a sieve tube, with sieve plates, *s.p.*, on the lateral walls. × 320.

Sieve plates often occur upon the lateral as well as the end walls of the segments (*fig.* 696). In Ferns, they are confined to the former position, and are very numerous in each tube.

In all plants lower in the scale than the Angiosperms, sieve tissue contains no companion cells.

Tissue much like sieve tissue occurs in certain regions of the thallus of one of the brown seaweeds (*Macrocystis*). In some others of the Laminarias similar structures are found, which are called *trumpet hyphæ*. It is, however, doubtful if their segments communicate.

The three forms of tissue so far described, viz. parenchyma, prosenchyma, and vascular tissue, combined in various ways, constitute the greater part of the plant body. Besides these, other forms are found in certain cases, having, however, a much more limited distribution. We may here briefly describe the most important of these.

Laticiferous Tissue.—Of this, two types occur. In the Euphorbias, and some plants belonging to the *Apocynaceæ* and *Asclepiadaceæ*, long, much-branched cells occur irregularly distributed throughout the plant (*fig.* 698). They have often thick walls, and are filled with a curious milky-looking fluid known as *latex*, which has given them the name of *laticiferous cells.* In the *Compositæ*, *Papaveraceæ*, and other Natural Orders, ramifying tubular structures are found, much like the former, but composed of rows of thin-walled parenchymatous cells, the partition-walls of which have been absorbed. These, from their containing a similar milky-looking or watery latex, are known as *laticiferous vessels* (*fig.* 697). Laticiferous vessels generally form an anastomosing network.

FIG. 697.

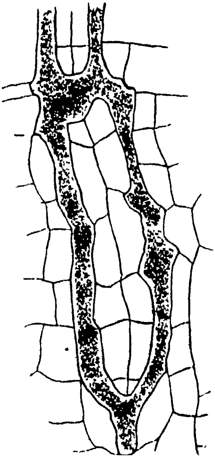


FIG. 698.

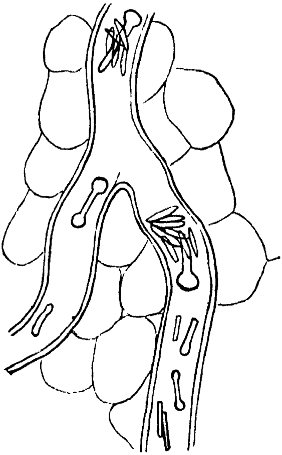


Fig. 697. Laticiferous vessels (cell fusions) in *Scorzonera* root. × 250.
Fig. 698. Part of laticiferous cell from stem of *Euphorbia splendens.* × 250.

A modification of this tissue is found in some monocotyledonous plants, forming what are known as *utricular vessels.*

These resemble laticiferous vessels in one particular, as they contain latex, in which are generally true raphides; on the other hand, they are unbranched and somewhat resemble sieve tubes, consisting as they do of long, broad cells with sieve-like septa. They were first noticed by Hanstein in the scales of the bulb of *Allium*.

FIG. 699.

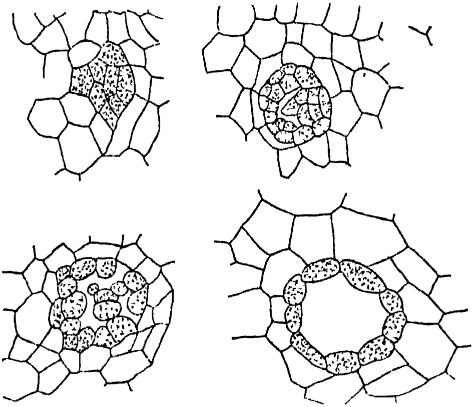


Fig. 699. Development of lysigenous gland in stem of *Hypericum*. The four figures represent successive stages. × 250.

FIG. 700.

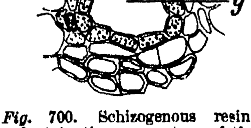


Fig. 700. Schizogenous resin-duct in the young stem of the Ivy (*Hedera helix*), transverse section (× 400). A. An early; B, a later, stage. *g*. The resin-ducts.

Glandular Tissue.—This has a much more limited distribution than the laticiferous tissue. It consists of single cells or of masses of cells of various shapes, sometimes long columns, sometimes ovoid or rounded collections. The cells which compose these masses are distinguished by their power of forming peculiar, generally aromatic, substances, which either remain stored in the cells or are passed out into intercellular spaces or cavities or to the exterior.

The cells are usually parenchymatous and filled with very granular protoplasm. The collections of such cells are commonly called glands, a name which is also applied to the cavities containing secretions, though the cells which formed them may have disappeared.

The glandular tissue may be a solid mass of cells, as in the nectaries of such flowers as *Fritillaria*; it may form a passage or cavity, lined with cells and containing the secretion, as in the resin canals of *Pinus* and other *Coniferæ*, or in the globular receptacles for essential oil in the leaves of the Rue, the rind of the Orange, &c.

The cavities may originate in two ways. In a transverse section of a very young stem or leaf of *Pinus*, or a stem of *Hedera* (*fig.* 700, A), there may be noticed here and there a somewhat conspicuous cell, which divides by walls at right angles to each other, usually into four. These cells are found in longitudinal sections to form columns which are frequently of some length. A transverse section of a little older stem shows in each position a small group of cells which separate from each other, so as to leave a passage in the centre. Longitudinal sections at this stage show that this passage or channel extends the whole length of the column; by continued separation and multiplication of the number of the cells surrounding the channel, a duct is formed which is lined by a delicate layer that secretes the resinous matter, and pours it out into the passage. In some cases the secretion is formed in the internal walls, in others in the interior of the cells. This mode of origin is called *schizogenous*.

In the case of the oil-glands of the Rue, Orange, &c., a small solid group or column of cells is formed from a single cell or a vertical row of cells, by repeated division. The protoplasm of these becomes charged with drops of the secretion, and the cell-walls in the centre of the mass degenerate and break down, leaving a cavity filled with the secretion and with the remains of the cytoplasm of the disintegrated cells. Sometimes a peripheral layer does not disappear, so that the cavity remains lined with secreting cells. This mode of origin is termed *lysigenous* (*fig.* 699).

Occasionally both these methods may be met with in the formation of a gland.

Besides these forms of glandular tissue isolated cells or single rows of cells containing secretions are not uncommon. They may contain tannin, mucilage, or other products. They are generally parenchymatous and thin-walled.

CHAPTER III.

TISSUE SYSTEMS.

THE combination of cells into tissues which we have now examined is an indication that in a cell mass such as constitutes the body of most plants there exists a division of labour; that instead of each cell practically living for itself alone, as is the case in the simplest forms, each takes a definite share in the common life-work of the whole organism. This division of labour is the explanation of the differentiation of the structure which we have seen, the forms and arrangement of the cells being such as enable them to discharge their special functions most advantageously. Generally in the sporophyte of the Phanerogams and Vascular Cryptogams three main systems of tissue can be distinguished, each of which, though possessing broadly characteristic features of its own, may include more than one form of the tissues that have been described. These are the *epidermal* or *tegumentary*, chiefly protective in character; the *fibro-vascular*, which is mainly concerned in the conduction of fluids through the plant body; and the *ground* or *fundamental*, which is limited externally by the epidermal, and through which the fibro-vascular bundles pass. It is concerned principally with the metabolic work of the plant, and to a less degree with its mechanical support. None of these is exclusively the seat of the function assigned to it as its chief work. For instance, in most of the higher plants the epidermis is comparatively short-lived in many parts, and the work of protection is then taken up by particular tissues belonging to the fundamental tissue; the latter also often includes certain forms of conducting tissue. In the gametophytes of these and of the lower plants the differentiation into these three systems is not nearly so complete. In most only the epidermal and ground tissues are represented; in some only the latter. In some of the Mosses there is a central strand which though not truly vascular tissue is an indication of it.

In a growing point of the sporophytes mentioned above, whose structure has been described, indications of these three systems can be seen. In *fig.* 701 we have a representation of such a growing point. The outer layer of cells is seen to be continuous over the surface; it forms the *dermatogen*, which when adult becomes known as the *epidermis*. Centrally there is a mass of cells which show a general tendency to become longer than broad. This is known as the *plerome*; it develops generally into a bulky strand or cylinder of tissue known as the *stele*, in which well-defined collections of cells known as *vascular bundles* originate. Between the two there is a cylinder of tissue known as the *periblem*, which consists of *ground* or *fundamental* tissue, and becomes the *cortex*. In some growing points with small-celled meristems these three systems can be seen to originate in different layers of the meristem. In others the differentiation cannot be traced so far in the direction of the apex. In further development the stele is usually found to contain a certain amount of ground tissue besides the vascular bundles. We may therefore distinguish between *stelar* and *extra-stelar* ground tissue, the latter alone arising from the periblem, and constituting the cortex.

FIG. 701.

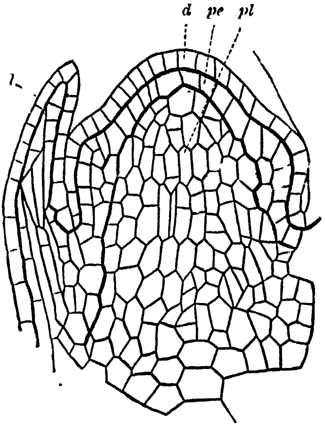


Fig. 701. Growing point of the stem of a Dicotyledon. After Douliot. *d.* Dermatogen. *pe.* Periblem. *pl.* Plerome. *l.* Young leaf. The dark lines are exaggerated to indicate the limits of the plerome, periblem, and dermatogen.

THE EPIDERMAL TISSUE SYSTEM.

The body of nearly all plants which consist of a mass of cells is covered by a thin membrane composed of a sheet of cells. In the shoots of the higher plants this is derived from the entire dermatogen, and is known as the epidermis. It is usually only one cell-thick. In the roots the dermatogen gives rise at the apex to many layers of cells, forming the root-cap. In most Dicotyledons the innermost of these layers can be traced backwards over the surface, and bears the root-hairs, being known as the *piliferous layer.* In the roots of Monocotyledons and Cryptogams the true epidermis only persists at the apex, forming as before a many-layered root-cap. The rest of the root bears a piliferous layer, but it is in these cases the external layer of the periblem. The external layer of roots is consequently not a true epidermis; it is generally termed the *epiblema.*

FIG. 702.

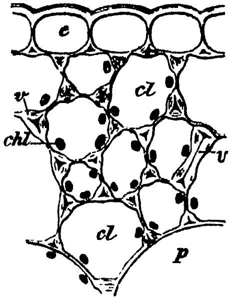


Fig. 702. Transverse section of the petiole of a species of *Begonia.* *e.* Epidermis with cuticle above and hypoderma below, the latter formed of collenchymatous cells *cl, cl,* with thickened angles *v, v.* *chl.* Chlorophyll granules. *p.* General parenchyma, below hypoderma. After Sachs.

The cells of the dermatogen are somewhat oblong when seen in section, and are usually rich in protoplasm. As they grow older the walls become thickened, especially on the outer surface (*fig.* 702). Viewed from the surface they present a great variety of outline. The thickened walls become cuticularised to a variable extent, particularly their outer layers. In very thick-walled cells these outer cuticularised layers can often be stripped off, forming a sort of detachable structureless membrane, termed the *cuticle* (*fig.* 706). As the cells become adult they lose a great deal of their protoplasmic contents,

FIG. 703.

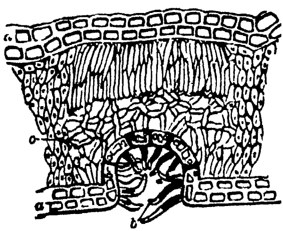


FIG. 704.

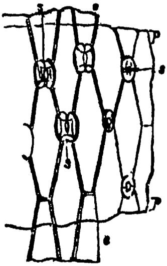


Fig. 703. Vertical section through the leaf of a *Banksia.* *a, a.* Epidermis. *c.* Spongiform parenchyma. *b.* Hairs which are contained in little depressions on the under surface of the leaf, and at whose base peculiar stomata are found. After Schleiden.——*Fig.* 704. Epidermal tissue from the leaf of the Iris (*Iris germanica*). *p, p.* Cuticle. *s, s, s.* Oval stomata. *e, e.* Epidermal cells. After Jussieu.

and are filled with little more than water. The outer layers of the cuticle are often impregnated with wax, which sometimes is so great in quantity that a coating of waxy particles is found to be deposited on the exterior.

The cells of the epidermis in the lower plants and in some aquatic members of the Phanerogams contain chloroplastids, but as a general rule these are absent from them. The epidermis of aquatic plants does not become cuticularised.

Though usually only one cell thick, there are many cases where the epidermis consists of several layers. In the leaves of certain plants, such as *Ficus* (*fig.* 642), there are two or three layers. In the root-cap (*fig.* 763) we have several layers; in various aerial roots, such as those of epiphytic Orchids, there is a special epiblema consisting of many layers of cells which have curiously pitted walls and no cell-contents.

FIG. 705.

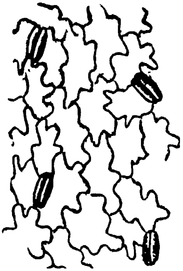


FIG. 706.

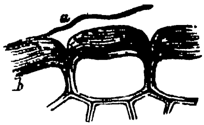


Fig. 705. Sinuous epidermis with stomata, from the garden Balsam.——*Fig.* 706. Vertical section of the epidermis of *Hoya carnosa* treated with caustic potash. *a*. The detached cuticle. *b*. The partially cuticularised layers of the outer walls of the epidermal cells. After Von Mohl.

The cells of the epidermis are, with certain exceptions, in close contact with each other, forming a continuous covering to the plant without any intercellular spaces. This continuous coating is, however, interrupted at the apex of shoots whose growing point is marked by the presence of an apical cell (*fig.* 707), the latter always extending to the surface. In some shoots, as in the thallus of *Pelvetia*, one of the *Fucaceæ*, the growing point is depressed, in consequence of the growth of the lateral segments of the apical cell (*fig.* 708).

The epidermis of the shoot in all the higher sporophytes possesses a number of apertures, produced by the splitting of the common wall of two contiguous cells, known as guard-cells.

immediately over a conspicuous intercellular space of the subjacent region. These apertures, known as *stomata*, may be regarded as the means of communication between the intercellular space system and the outer air (*figs.* 709, *s*, and 710, s).

FIG. 707.

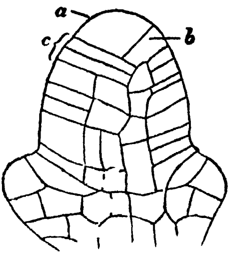


FIG. 708.

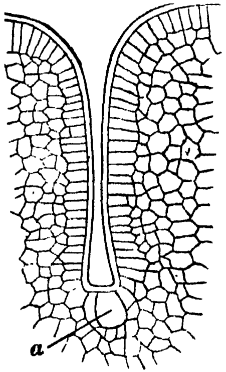


Fig. 707. Growing point of shoot of *Equisetum arvense*. × 250. *a*. Apical cell. *b*, *c*. Successive segments cut off from it.——*Fig.* 708. Growing point of the thallus of *Pelvetia*. *a*. Apical cell. × 250. After Kny.

They originate by the vertical division of a mother-cell into two. The partition between the latter thickens slightly, and splits so as to form an opening between them, leaving them still attached to each other by their ends. The split constitutes the stoma, and the two cells are the *guard-cells*. They are commonly of a more or less semilunar form, and contain some chlorophyll grains; when they are full of water their form causes them to become curved, so that the orifice is widely open; when they lose their water they relax and their edges come into contact, closing it.

FIG. 709.

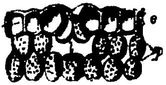


Fig. 709. Vertical section of a portion of the epidermis of a leaf, showing a stoma slightly depressed. *s*. The stoma. *e*, *e*. Epidermis. *p*. Parenchyma beneath the epidermis. *l*. Intercellular space into which the stoma opens.

Upon making a vertical section through a stoma we usually find that the guard-cells are placed nearly or quite on a level with the rest of the epidermis. In some cases, however, and especially when situated upon leaves of a leathery or hardened texture, the stomatal cells are depressed below the others; in some rare instances, again, they are elevated above them.

The stomata vary in form and position in different plants, and in different parts of the same plant, but they are always the same in any particular part of a plant. They are usually placed singly upon the epidermis, at regular (*fig.* 704) or irregular intervals. In *Banksia* and some other plants we find little cavities in the under surface of the leaves which contain a number of hairs (*fig.* 703, *b*), and between the latter very small stomata.

The distribution of stomata over the surface of the sporophyte varies very much. They are found especially upon leaves, more particularly on the under surface. On the floating leaves of aquatic plants, such as the Water-lily, however, we find them only on the upper surface; while in succulent leaves and such as are placed vertically the stomata are equally distributed on the two surfaces. They occur also on the young green stems and branches of plants, and on parts of the flower. In those plants which have no foliage leaves, e.g. the *Cactaceæ*, they abound upon the green succulent stems. They are absent, as a rule, from roots and all submersed parts of plants.

FIG. 710.

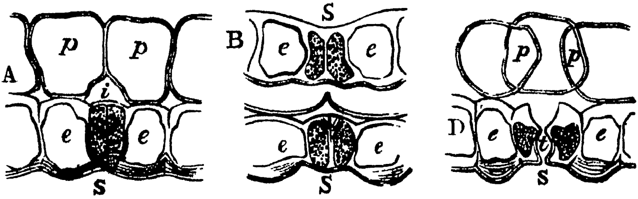


Fig. 710. In these figures the development of the stoma of *Hyacinthus orientalis* is represented from the first division of the mother-cell in A into two daughter-cells, to the complete separation shown in D. *p, p.* Parenchyma of the leaf. *e, e.* Epidermis cells. S. Stoma. *i.* Air-cavity. After Sachs.

The number of stomata varies considerably. The following table will give some idea of their abundance in leaves, and it will be observed that the number of stomata is usually greatest in those leaves from whose upper surface they are entirely absent.

Stomata in one Square Inch of Surface.

	Upper surface	Lower surface
Mezereon	none	4,000
Pæony	none	18,790
Vine	none	13,600
Olive	none	57,600
Holly	none	68,600
Laurustinus	none	90,000
Cherry-laurel	none	90,000
Lilac	none	160,000
Hydrangea	none	160,000
Mistletoe	200	200
Tradescantia	2,000	2,000
House Leek	10,710	6,000
Garden Flag	11,572	11,572
Aloe	25,000	20,000
Yucca	40,000	40,000
Clove Pink	38,500	38,500

Though the guard-cells of stomata can usually vary the size of the opening, or altogether close it, according to circumstances, this is not universally the case. In some plants large stomata occur whose guard-cells cannot change their form so as to do this. These, which are known as *water-stomata* or water-pores, are chiefly concerned in the excretion of water, the ordinary form being adapted to regulate the escape of watery *vapour* only.

The cells of the epidermis are often prolonged outwards in the form of *hairs* or *trichomes*. They are borne upon both sporophytes and gametophytes. The simplest ones are formed by the outgrowth of single cells of the general surface, which take the form of papillæ or projections, making the surface rough or velvety, as that of the stigmas of many flowers. The root-hairs are long outgrowths of this kind, arising from the root (*fig.* 711). Generally, instead of remaining single, the originating cell, or mother-cell, divides in various ways. The part, usually a single cell, which is embedded among the epidermal cells is then called the *foot*, while the free part which extends outwards forms the *body* of the hair. We frequently find a multicellular hair of this kind consisting of a chain of cells. Often the first free cell cut off from the mother-cell branches copiously, the branches sometimes growing horizontally, sometimes vertically. Hairs of various forms are thus produced, among which may be mentioned the stellate hairs of the Ivy, of *Deutzia scabra*, and the peltate hairs of many plants. The body of a stellate hair may be unicellular or multicellular.

Larger hairs frequently arise from small groups of epidermal cells. These also present the form of a foot and a body.

Scales are modifications of stellate hairs. They may be defined as flattened, membranous, more or less rounded plates, attached by the centre to the epidermis, and presenting a more or less irregular margin from the unequal prolongation of the component cells. These scales are particularly abundant on the surface of some plants, such as *Elæagnus*, to which they communicate a scurfy or silvery appearance.

Other modifications of hairs which are allied to scales are the *ramenta* or *ramentaceous hairs* so frequently found upon the stems and petioles of Ferns. These consist of a single layer of cells which form a brownish flattened scale attached by its base to the surface of the epidermis from which it grows.

Hairs must be distinguished from prickles, warts, &c., which arise from the sub-epidermal tissue as well as the epidermis, and which have been termed *emergences*. These, again, should be carefully distinguished from *thorns*, which we have seen to be abortive branches.

The ordinary hairs described above may be empty, or they may contain fluid of a watery nature, either colourless or coloured.

FIG. 711.

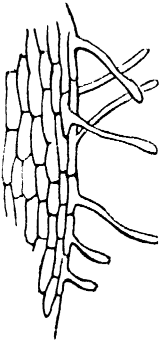


Fig. 711. Root-hairs on the surface of a young root.

Hairs occur upon various parts of plants; their more common position is upon the leaves, stems, and young branches, but they may also be found on the flower-stalks, bracts, parts of the flower, the fruit, and the seed. A remarkable form occurs on young roots, where cells of the epidermis produce long tubular outgrowths which become very closely applied to the particles of soil. These are termed *root-hairs* (*fig.* 711). The hairs which occur on the parts of the flower frequently play an indirect part in the process of fertilisation by collecting the pollen which falls from the anthers; hence such are termed *collecting hairs*. The collecting hairs which occur on the style of the species of *Campanula* are peculiar from their upper end retracting within their lower at the period of pollination.

Besides the forms of glandular tissue already described, certain secretions are formed in peculiar hairs. These may arise from a single cell of the epidermis or from several. In some cases the secretion is formed inside one or more cells; in others it is due to a degeneration of the cell-wall, and then accumulates under the cuticle of the terminal cell or cells (*figs.* 712 and 713). These glandular hairs or external glands may be sessile or stalked. If sessile they present various appearances,

FIG. 712.

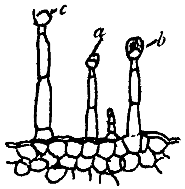


FIG. 713.

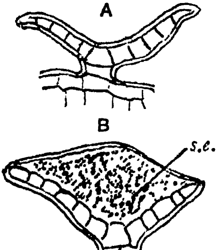


FIG. 714.

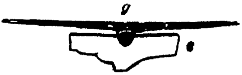


FIG. 715.

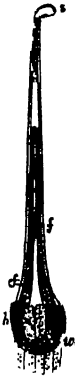


Fig 712. Glandular hairs from *Primula sinensis*. *a.* Young hair. *b.* Hair showing secretion formed in the cell-wall of the terminal cell. *c.* Hair after discharge of the secretion.——*Fig.* 713. Glandular hairs from Hop. A. Young hair. B. Mature hair. *s.e.* Secretion under the cuticle.——*Fig.* 714. Sting of a species of *Malpighia*. *e.* Epidermis. *g.* Glandular apparatus.——*Fig.* 715. Sting of the common Nettle (*Urtica dioica*), consisting of a single cell with a bulbous expansion at its base, *h*, and terminated above by a swelling, *s*, and containing a granular irritating fluid, *f*, *f*. *w e.* Epidermal cells surrounding its base.

and consist either of one secreting cell, or of two or more. Those with one secreting cell placed above the level of the epidermis are frequently termed *papillæ*.

Hairs with a very large and swollen terminal cell, which serves as a water reservoir, occur upon the surface of the Ice-plant (*Mesembryanthemum crystallinum*), and it is to their presence that the peculiar appearance of that plant is due.

When a sessile gland contains an irritating fluid, and is prolonged above into one or more hair-like processes, which are placed horizontally (*fig.* 714), or vertically (*fig.* 715), we have a *sting* formed.

In the Nettle (*fig.* 715) the sting consists of a single cell, enlarged at its base, *b*, by an irritating fluid *f*, *f*, which it contains, and tapering upwards to near its apex, where it again expands into a rounded or pointed head, *s*. The enlarged base is closely invested by a dense layer of epidermal cells, *w e*, which forms a kind of case to it. When a Nettle is touched lightly the knob-like head, *s*, is broken off, and the sharp point of the sting then left enters the skin, while the irritating fluid is pushed up at the same time into the wound by the pressure occasioned by the elastic force of the surrounding epidermal cells, *w e*.

THE GROUND OR FUNDAMENTAL TISSUE SYSTEM.

Underneath the epidermis in the gametophyte of all cellular plants which show any differentiation of tissues, we find a mass of cells which constitutes the ground or fundamental tissue.

FIG. 716.

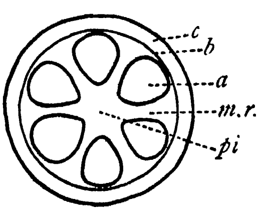


FIG. 717.

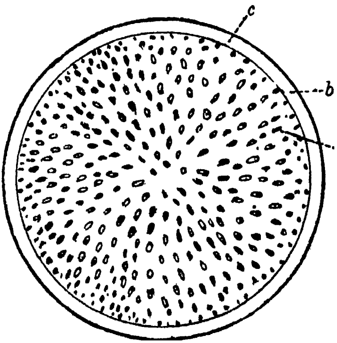


Fig. 716. Diagram of section of monostelic stem of dicotyledonous plant. *c.* Cortex. *b.* Limit of stele. *a.* Vascular bundles. *m.r.* Medullary rays. *pi.* Pith.——*Fig.* 717. Diagram of section of monostelic stem of monocotyledonous plant. *a.* Vascular bundles. *c.* Cortex. *b.* Limit of stele.

In the sporophyte of the vascular plants, which is in their case the prominent form, we can distinguish in addition a central stele or steles, largely composed of vascular tissue, but containing some fundamental or conjunctive tissue interspersed among the latter (*figs.* 716 and 717). The fundamental tissue in these forms may be spoken of as *extra-stelar* and *intra-stelar* respectively, the former derived from the periblem, the latter from the plerome. If there is a single stele the extra-stelar fundamental tissue constitutes what is known as the cortex, and has the form of a hollow cylinder. It is the region which is continuous with the periblem of the growing point (*fig.* 701).

Extra-stelar Ground Tissue, or Cortex.

Generally ground tissue is composed of parenchyma, the cells being polygonal in outline and thin-walled, with intercellular spaces between the cells. Sometimes the walls are slightly thickened, and then show pits upon their surfaces. The tissue may contain, in addition, fibres or masses of sclerenchyma or collenchyma, especially when the vascular bundles of the stele are not well developed.

These masses are arranged in different ways, sometimes as a sheath underlying the epidermis, sometimes as isolated strands in the substance of the cortex, or the external layer of the stele, sometimes as sheaths or masses, in contact with the vascular bundles. They may be connected together in various ways, and thus form a supporting tissue supplementing the vascular bundles. These sclerenchymatous and collenchymatous masses together with the hardened elements of the vascular bundles are often spoken of as the *stereome* of the plant.

The cells of the parenchyma retain their protoplasm, and are largely concerned in the metabolic processes of the plant. The outer layers frequently contain chloroplastids, starch, &c. Generally in the axis of vascular plants the external layers of the cortex differ to a variable extent from those nearer the centre, and can be recognised as a well-marked region, often called the *hypoderma.* The innermost layer, which abuts upon the stele, or steles if there are more than one, constitutes the *endodermis.*

The hypoderma is often found to contain supporting tissue. In many stems it is composed entirely of layers of sclerenchyma, as in the rhizomes of many Ferns and species of *Equisetum.* In succulent petioles it is often composed of collenchyma.

In the hypoderma of roots the second layer of the cortex is known as the *exodermis* (*fig.* 718). Its walls are usually thin, with a ladder-like thickening band extending round their radial and upper and lower surfaces. In Monocotyledons it persists throughout the life of the root; in Dicotyledons it is soon shed and replaced by a deeper corky formation. In some plants the exodermis is several layers of cells in thickness.

In foliage leaves the hypoderma sometimes shows a large development of sclerenchyma, as in many of the *Coniferæ* (*fig.* 719, *h*). In the leaves of certain Monocotyledons it consists of *aqueous tissue*, being made up of thin-walled parenchymatous cells which contain little more than water, and are packed close together without intercellular spaces. Some succulent leaves have their ground tissue entirely composed of this.

FIG. 718.

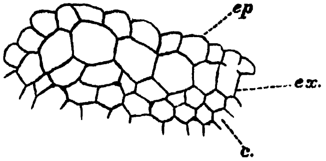


Fig. 718. Outer part of root of Hyacinth. *ep.* Epiblema. *ex.* Exodermis. *c.* Cortex. ×250.

The general ground tissue shows a peculiar character in the wings of foliage leaves, the cells, though parenchymatous, not being at all like those of the stem. On one or both sides they are found to be elongated and arranged in one or several rows, with their long axes at right angles to the surface. They have a number of chloroplasts embedded in their protoplasm. From their mode of arrangement they have been called *palisade tissue* (*fig.* 720, *p.t.*). If this tissue is only on the upper side of the leaf, the lower side shows more irregularly arranged chlorophyll-containing tissue which from the looseness of its arrangement has been called *spongy parenchyma* (*fig.* 720, *s.p.*). It is chiefly remarkable for its abundant intercellular spaces.

FIG. 719.

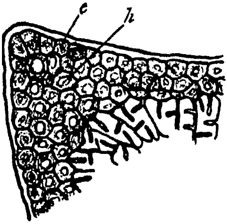


FIG. 720.

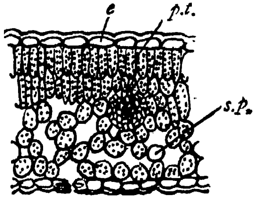


Fig. 719. Portion of transverse section of leaf of *Pinus*. *e.* Epidermis. *h.* Hypoderma.——*Fig.* 720. Section of leaf of *Beta*. *e.* Epidermis. *p.t.* Palisade tissue. *s.p.* Spongy parenchyma.

The general ground tissue of the cortex may contain many other kinds of tissue already described; resin ducts, laticiferous tissue, &c., all occur in different plants.

Crossing the cortical tissue of the stem we find fibro-vascular strands joining the meristeles of the leaf with the main axial stele. As we shall see later, the leaves are derived from the periblem and dermatogen of the stem, the plerome taking no part in their formation. We find that parts of the periblem give rise in this way to vascular tissue, though the chief place of origin of the latter is the plerome. The vascular strands continuous with those of the leaf are known as *leaf-trace bundles.*

In rare cases certain strands of vascular tissue are found in the cortex, developed longitudinally down the stem for some distance parallel to the stele. These are generally leaf-trace bundles, which ultimately curve and join the bundles of the stele.

FIG. 721.

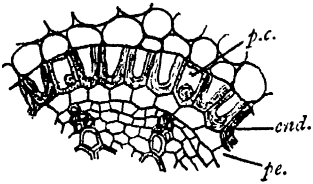


FIG. 722.

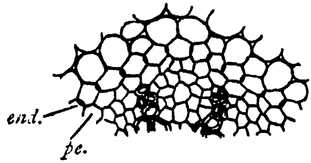


Fig. 721. Endodermis and pericycle of root of *Iris*. *end.* Endodermis. *p.c.* Passage cell. *pe.* Pericycle.——*Fig.* 722. Endodermis of root with cogged thickening.

The innermost layer of the cortex is the endodermis. It forms a band of peculiar character round the stele, or round each stele if there is more than one. The cells composing this layer are sometimes thickened uniformly, or on the side facing the stele and on the lateral walls (*fig.* 721): they are more commonly thin-walled with a peculiar ladder-like thickening band extending round their radial and upper and lower surfaces. This in section gives the appearance of *fig.* 722, *end.* In other cases, particularly in stems, the endodermis is only recognisable with difficulty.

In rare cases, as in the roots of *Equisetum* and the stems of certain Ferns, the endodermis consists of two layers.

In the cortex of all those stems which grow in thickness a further modification of ground tissue is developed. This is the tissue known as *cork*. It is not confined to the cortex, though the latter is the chief seat of its formation. It may be formed also in the cells of the epidermis or in some part of the tissue of the stele. In most cases it arises from the outermost layer of the hypoderma becoming merismatic, and dividing repeatedly by tangential walls, forming a layer, often several cells thick, of brick-shaped cells without interspaces (*fig.* 723, *per*). The cell-walls remain thin, but generally become completely suberised. The merismatic layer of cells is known as the *phellogen* (*fig.* 723, *ph.*); it is classed as a *secondary* meristem, the cells regaining the power of dividing after having assumed the condition of permanent tissue.

FIG. 723.

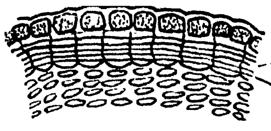


Fig. 723. Outer portion of cortex of young stem of Lime. *ph.* Phellogen. *per.* Cork.

Sometimes it is not the outer layer of the hypoderma which becomes phellogen, but one deeper in the cortex. The depth varies in different stems: it may be seated so far inwards as to be within the limits of the stele. It never extends within the wood of the vascular bundles. Sometimes many phellogens are developed in succession, each of which gives rise to a cork layer.

FIG. 724.

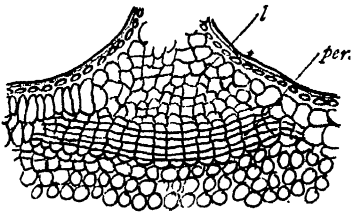


Fig. 724. Section of Lenticel (*l.*). *per.* Periderm.

Whatever be its origin, it gives rise to the same forms of tissue, externally *cork*, and internally often to a secondary cortex known as *phelloderm*. The phellogen and the tissues which it forms both internally and externally have been called *periderm* by some authors; by others the term periderm is restricted to the layers formed on the outside only of the phellogen, the phelloderm and the phellogen being distinguished from it.

A variety of ordinary periderm is formed in some cases by strata of thickened or hardened cells occurring among the thin-walled suberised ones. This is the case when the activity of the same phellogen is maintained for several years. In roots, cork is found less frequently in the hypoderma; generally the phellogen arises in the external layer of the stele, known as the *pericycle*. It may or may not be accompanied by a development of phelloderm. In leaves the occurrence of cork is rare. It is found in the scales of the winter-bud of the Horse-chestnut, and in the petioles of *Hoya carnosa* and a few other plants.

FIG. 725.

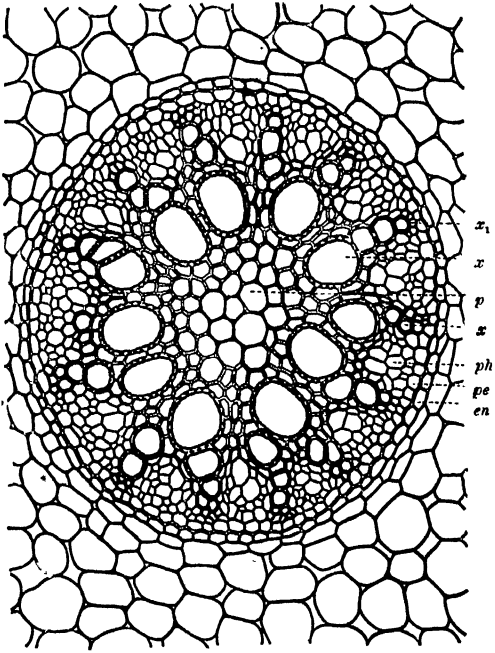


Fig. 725. Section of stele of root. After Kny. *en*. Endodermis. *pe*. Pericycle *x*. Xylem bundles, the protoxylem, x_1, abutting on the pericycle. *ph*. Phloëm bundles alternating with the bundles of xylem. *p*. Pith, or conjunctive tissue of the stele.

Cork is also formed as a covering over any portion of the interior of a plant which is exposed to the air in consequence of injury. The injury stimulates the exposed uninjured cells to merismatic activity, and a phellogen is formed over the wound.

Cork is formed in all stems and roots that increase in thickness; it occurs in most Dicotyledons and Gymnosperms; some

Monocotyledons; in the *Marattiaceæ* and in *Botrychium* among the Cryptogams. It is not found in herbaceous plants.

The development of cork and its effect upon the structure of the stem and root in woody plants will be further discussed in connection with the anatomy of these members.

From the character of its cell-walls and the arrangement of its cells, the cork forms a layer impervious to the passage of water or gases. At certain places in both stems and roots special structures are developed to allow of the admission of air to the tissues underlying it. These are *lenticels*. In stems they are generally developed under places in the epidermis where stomata are present. Each consists of a little rounded spherical mass of corky cells arranged loosely together. They become exposed to the air by rupture of the epidermis above them. In the autumn a formation of cork takes place under them, by which the communication with the exterior is cut off till the succeeding spring (*fig.* 724).

Intrastelar Ground Tissue.

The intrastelar ground tissue is somewhat varied in its disposition. In a monostelic stem or root the whole stele is surrounded by a layer of usually parenchymatous tissue abutting on the endodermis and extending inwards for a variable distance. This is known as the *pericycle.* In roots (*fig.* 725, *pe*) it is

FIG. 726.

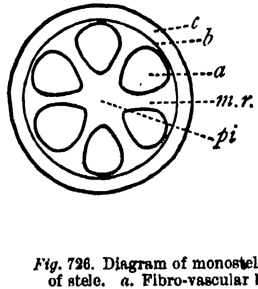


FIG. 727.

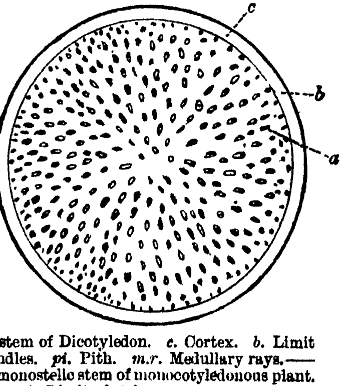


Fig. 726. Diagram of monostelic stem of Dicotyledon. *c.* Cortex. *b.* Limit of stele. *a.* Fibro-vascular bundles. *pi.* Pith. *m.r.* Medullary rays.—*Fig.* 727. Diagram of section of monostelic stem of monocotyledonous plant. *a.* Vascular bundles. *c.* Cortex. *b.* Limit of stele.

generally composed of a single layer of cells; in most stems, of several layers. The cells are usually parenchymatous, but bands, rings, or patches of sclerenchyma may be present. Frequently a number of such thickened cells abut upon the vascular bundles. In roots merismatic tissue is often developed in the pericycle. In consequence of this, secondary formations of both vascular tissue and periderm occur there. In the stem and petiole glandular tissue is frequently met with.

FIG. 728.

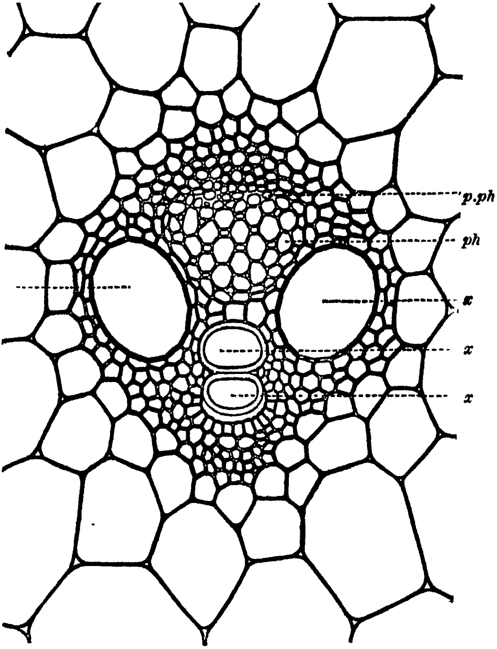


Fig. 728. Collateral bundle from stem of a Monocotyledon. *ph.* Phloëm. *x.* Xylem vessels. *p.ph.* Protophloëm. The bundle is surrounded by a small-celled sheath of sclerenchyma. After Kny.

The disposition of the rest of the intrastelar ground tissue depends upon the arrangement of the vascular bundles in the stele. We may distinguish several types. The vascular bundles, few in number, may be arranged as a circle of wedge-shaped bodies just within the pericycle, as in the stems of Dicotyledons and most Gymnosperms. Then this part of the conjunctive tissue consists of a central mass or *pith*, and a number of strands extending between the latter and the pericycle, constituting the so-called *medullary rays*. The vascular bundles may be numerous, and arranged irregularly, or in a series of circles, in the stele, as in the stems of Monocotyledons. Sometimes the centre of the stele of the latter is free from them, and we can speak of a pith. It is usually, however, very ill-defined. It is customary not to speak of pith in these stems, but merely interfascicular ground tissue. The latter is generally most conspicuous towards the centre of the stele. It often contains sclerenchyma, either in isolated patches, or in the form of sheaths surrounding the vascular bundles (*fig.* 728). In many roots the part of the stele within the pericycle consists of a solid vascular cylinder containing no conjunctive tissue at all, or only a little dipping in from the pericycle in the intervals between the bundles; while in other cases there may be a central hardened pith closely surrounded by the bundles, and not communicating with the pericycle by regular medullary rays.

Fig. 729.

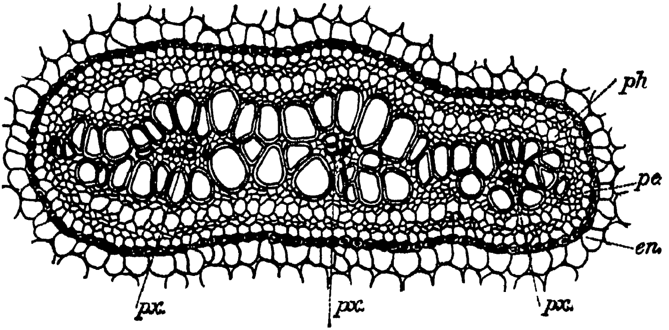


Fig. 729. Stele of stem of Fern, composed of three fused concentric bundles *en.* Endodermis. *pe.* Pericycle. *ph.* Phloëm. *pr.* Groups of protoxylem.

• In Dicotyledons isolated vascular bundles sometimes occur in the pith. Where a large pith exists the cells of it tend after a time to break up and disappear, forming hollow stems, as in many members of the *Umbelliferæ*. These hollow stems are extreme instances of lysigenous formations.

In polystelic stems each stele, in addition to its envelope of endodermis, is surrounded by a layer of pericycle. Such steles are usually composed of solid vascular tissue, and do not show intrastelar ground tissue, both pith and interfascicular ground tissue being absent (*fig*. 729).

THE VASCULAR TISSUE SYSTEM.

THE STELE.—We have seen that the centre of the tissue of the growing point, which has been named the plerome, develops into a solid strand of complex character, forming the *stele*. Usually this remains single throughout the axis, and the plant is termed *monostelic*. The arrangements of its parts are different in the stem and the root, but there is a single central cylinder running throughout the whole axis. Separate portions, known as *meristeles*, pass outwards from it to the leaves. If a section of such a stele be taken a little way behind the growing point, there can be seen variously placed in it a number of collections or groups of small cells, very well defined and marked off conspicuously from the rest of the tissue. These are sections of strands of cells, called *procambium strands*, which a little later are transformed into the *vascular bundles*. Great differences appear in different steles in the composition and arrangement of the latter, as already described. Between them we find ground tissue; and a layer of the same, the pericycle, surrounds

FIG. 730.

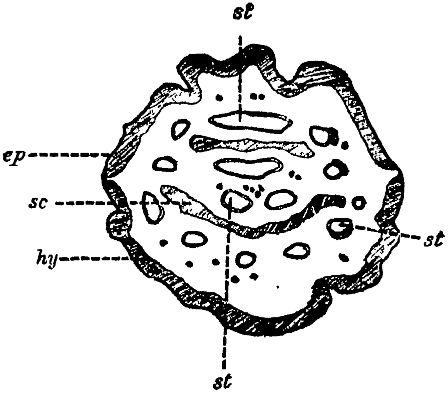


Fig. 730. Polystelic stem of Fern. *st*. Steles. *sc*. Bands of sclerenchyma. *hy*. Hypodermal sclerenchyma. *ep*. Epidermis.

the whole stele externally, lying in contact with the endodermis. The general arrangement of the intrastelar ground tissue has already been described.

In many stems this monostelic structure is not found. Several separate steles sometimes exist, each containing vascular bundles and surrounded by layers of pericycle and endodermis. Such stems are known as *polystelic* (*fig.* 730). In some stems of this type the separate steles, or some of them, are fused together for variable distances along their course. The pericycle and endodermis then surround the mass formed by such fusion, and the arrangement is called *gamo-desmic.* If the original plerome is not continued into a single cylinder surrounded by an endodermis, but instead gives rise to a number of strands, each consisting of a single vascular bundle surrounded by a pericycle and endodermis, we have the condition called *astely* or *schizostely.* This differs from polystely in that each stele in the latter case is composed of two or more vascular bundles.

The formation of the several steles in polystelic stems is due to the differentiation of the cells of the plerome varying at different times during the growth of the axis or stem. The endodermis of the steles is not in this case, and in that of astely, derived entirely from the periblem, but part or all of it springs from the plerome.

The Pericycle.—As we have seen, this portion of the stele is to be regarded as ground tissue. It presents certain characteristic features in different portions of the axis. Generally, its cells are thin-walled and parenchymatous, and form a continuous layer over the stele. In the stem it is usually several layers of cells thick, and may contain a variety of tissues, including bands or strands of collenchyma, sclerenchyma, or glandular tissue. In the root it is usually only one cell thick, and the cells are all parenchymatous. An exception is found in nearly all Gymnosperms, where it is many-layered. There is, however, a good deal of variety in its construction in many roots. It is not always continuous, being absent behind the woody bundles of many grasses and sedges and some other Monocotyledons, in which the protoxylem cells abut directly on the endodermis. In other cases its continuity is interrupted behind the bundles of the bast, particularly in several aquatic Monocotyledons.

Though generally of uniform thickness in roots, this is not without exception. It may be several cells thick opposite to the bast bundles, as in the aerial roots of some Orchids, or behind the wood bundles, as in some *Leguminosæ*. Where it is many-layered the cells may become sclerotised.

The pericycle is often the seat of secondary formations, due to certain of its cells becoming merismatic. Phellogens especially arise there, leading to the development of layers of cork. This is particularly the case in roots, where such phellogens extend completely round the stele. Another meristem giving rise to vascular elements is also developed in the pericycle of the root; but this is discontinuous, occurring only outside the bundles of the wood. Its separate parts join a number of strands of a similar meristem arising more deeply in the stele, forming thus a sinuous ring of generating tissue, or *cambium*.

FIG. 731.

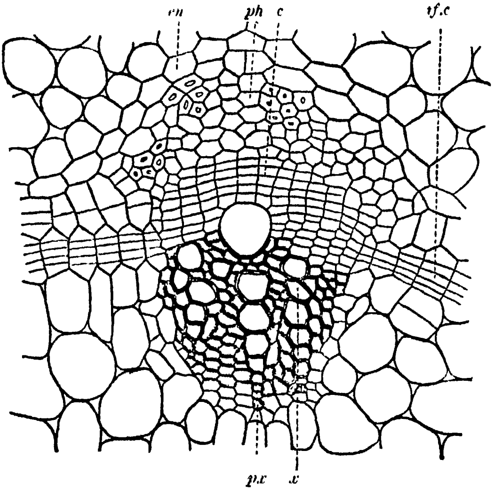


Fig. 731. Collateral bundle of *Ricinus*. *en.* Endodermis. *ph.* Phloem. *c.* Cambium. *p.x.* Protoxylem. *x.* Xylem. *if c.* Interfascicular cambium. After Sachs.

In all plants above the Vascular Cryptogams the pericycle gives rise to the lateral rootlets.

In some aquatic roots the pericycle is not present, but the vascular tissue of the stele abuts directly on the endodermis. This is the case also in the roots of the *Equisetaceæ*, and in the stems of *Salvinia* and *Azolla*, where the endodermis is two-layered.

The Vascular Bundles.—Each fully differentiated vascular bundle consists usually of two parts, called the *xylem*, or *wood*, and the *phloëm*, or *bast*. The xylem is made up of what has been described as tracheal tissue mixed with a certain amount of wood parenchyma and wood fibres. Its walls are always lignified, and usually the cells are empty of contents. The phloëm is made up largely of sieve tissue with a little parenchyma. Associated usually with it is also a certain, sometimes a large, number of fibres. Bast or phloëm cells are never lignified, and always contain protoplasm.

FIG. 732.

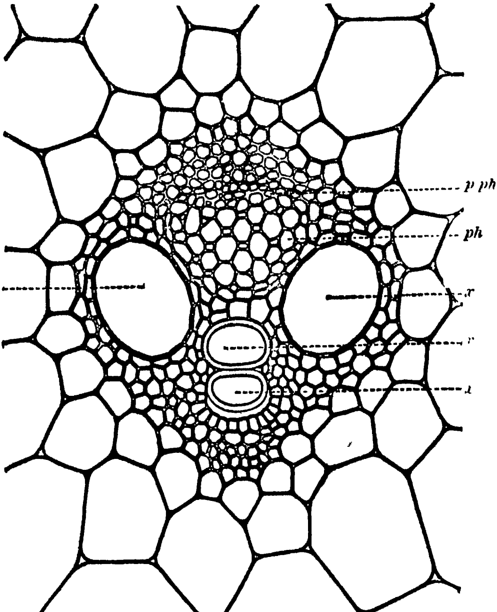


Fig. 732. Collateral bundle from stem of a Monocotyledon. *ph.* Phloem. *x.* Xylem vessels. *p.ph.* Protophloëm. The bundle is surrounded by a small-celled sheath of sclerenchyma. After Kny.

In addition to wood and bast certain bundles contain a thin layer of meristem, known as *cambium*.

The wood and bast, though usually combined into a single, or *conjoint*, bundle, may be separate, when they are spoken of as wood or bast bundles respectively.

The number of bundles in a stele varies greatly. They are usually very numerous in the stems of Monocotyledons (*fig.* 727) but few in those of Dicotyledons (*fig.* 726) and Cryptogams (*fig.* 729); there may be only one, as in the separate steles of schizostelic, and the smaller steles of polystelic, stems.

According to the mode of arrangement of the wood and bast, we have several types of vascular bundle. The two principal ones are the *collateral* and the *concentric*.

FIG. 733.

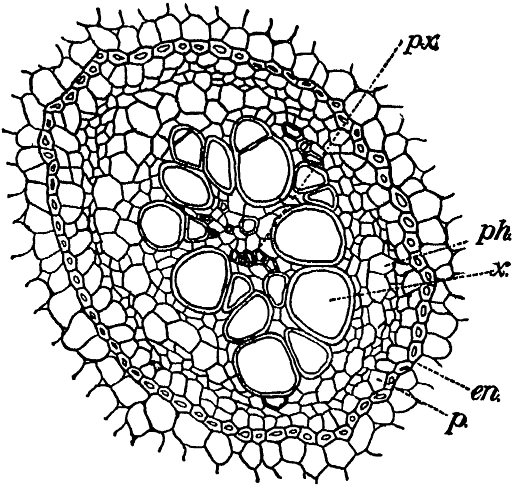


Fig. 733. Stele consisting of one concentric bundle from Fern stem. *en.* Endodermis. *p.* Pericycle. *ph.* Phloëm. *p.x.* Protoxylem. *x.* Xylem.

Collateral Bundles.—We distinguish again two kinds of these, one characteristic chiefly of the stems of Gymnosperms and Dicotyledons, the other of those of Monocotyledons.

In the first variety the bundle is roughly wedge-shaped, and the bast is placed behind the wood (*figs.* 731, and 743, B). The *orientation* of the bundle or its position in the stele is such that the narrow end of the wedge is directed towards the centre of the stem, and its broad end towards the periphery. In such a bundle the wood and the bast are generally separated by a band or layer of cambium. In some cases the wood and bast in a bundle of this type are in contact with each other, and there is therefore no cambium. Such a bundle is said to be *closed*, in

FIG. 734.

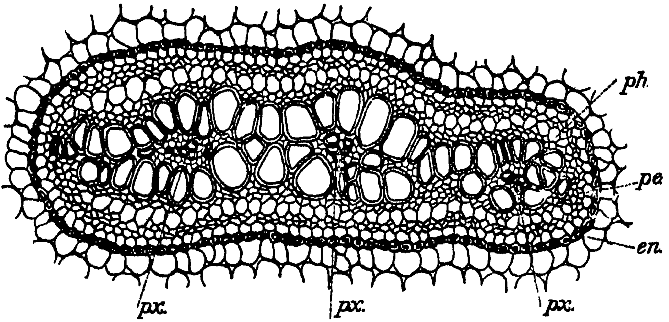


Fig. 734. Stele of stem of Fern (*Polypodium*), composed of three fused concentric bundles. *en.* Endodermis. *pe.* Pericycle. *ph.* Phloëm. *px.* Groups of protoxylem.

FIG. 735.

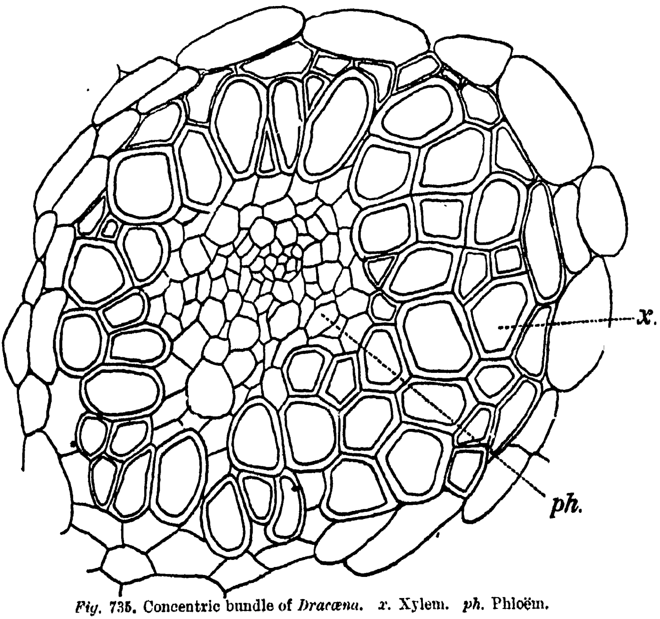


Fig. 735. Concentric bundle of *Dracæna*. *x.* Xylem. *ph.* Phloëm.

contradistinction to the form in which all three are present. A bundle possessing cambium, which is a meristem, is capable of continued increase in size, and is said to be *open*.

Some bundles of this type, occurring especially in *Cucurbitaceæ* and a few other natural orders, have a second bast bundle on the inner face of the wood. These are called *bicollateral*.

FIG. 736.

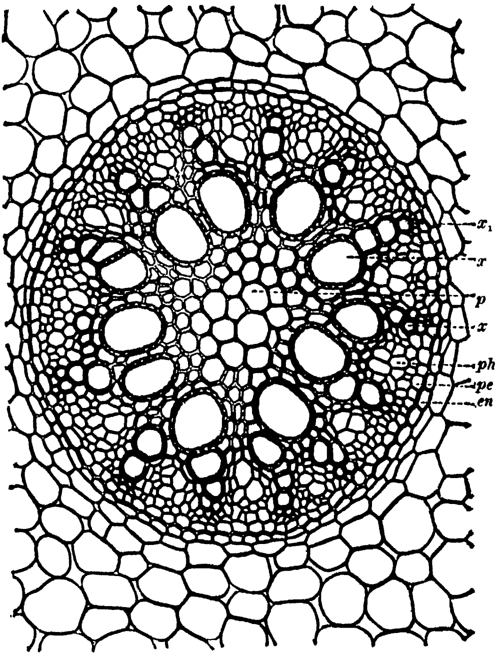


Fig. 736. Section of stele of root. After Kny. *en*. Endodermis. *pe*. Pericycle. *x*. Xylem bundles, the protoxylem, x_1, abutting on the pericycle. *ph*. Phloëm bundles alternating with the bundles of xylem. *p*. Pith, or conjunctive tissue of the stele.

The second variety of collateral bundle is not so markedly wedge-shaped. The wood is never separated from the bast by a cambium layer, but tends to curve partially round it as in *fig.* 782. The orientation of these bundles is similar to that of the first type.

Concentric Bundles.—Of this form we have again two varieties. In most the wood is central, and is surrounded by a layer of bast. This is seen in most Ferns (*fig.* 733). Sometimes an apparently concentric bundle is formed by the fusion of a number of wood bundles to form a single mass, which is surrounded by a ring of bast, itself the result of a fusion of separate bundles. Such a bundle is termed *gamodesmic*: it may be seen in many Selaginellas and Ferns (*fig.* 734). It is better regarded as a *stele.*

In the other variety we find the bast central, and the wood surrounding it. It occurs in a few Monocotyledons (*fig.* 735). Concentric bundles never contain any cambium.

FIG. 737.

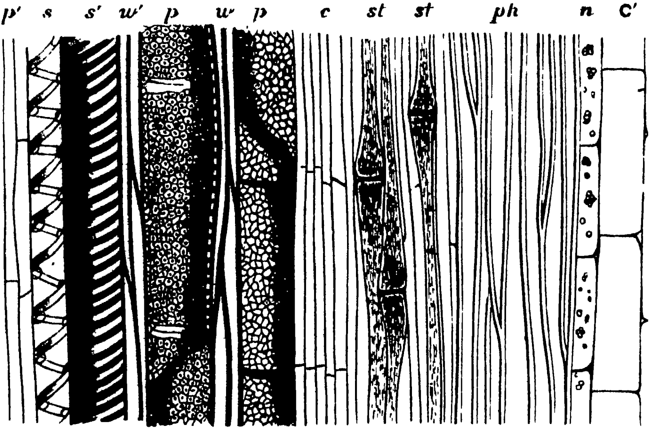


Fig. 737. Radial vertical section through a collateral fibro-vascular bundle from the stem of the Sunflower. *p'*. Pith. *s*, *s'*. Spiral vessels (*Protoxylem*). *w'*, *w*. Wood-cells. *p*, *p*. Pitted vessels. *c*. Cambium. *st*, *st*. Sieve tubes. *ph*. Fibres of the pericycle. *n*. Bundle-sheath. *c'*. Cortex. After Prantl.

The wood and bast bundles of the stele of the root are not conjoint but separate. They are said to be *radially* arranged as they lie side by side alternately in a circle round the axis (*fig.* 736). They are always separated by interfascicular ground tissue. A variety, which leads to an apparently very complicated structure in the adult form, is found in the stems of *Lycopodium* and some allied plants, where the separate bundles ultimately become gamodesmic (*fig.* 756).

The longitudinal course of the bundles in the stele varies very much in different stems, and will be best described when dealing with the structure of the latter.

In some cases they can be traced up to the plerome, beyond the insertion of the leaves, when the bundles are called *cauline*. In other cases they are continuous with the bundles in the young leaves. Being common to stem and leaf, they are known as *common* bundles.

FIG. 738.

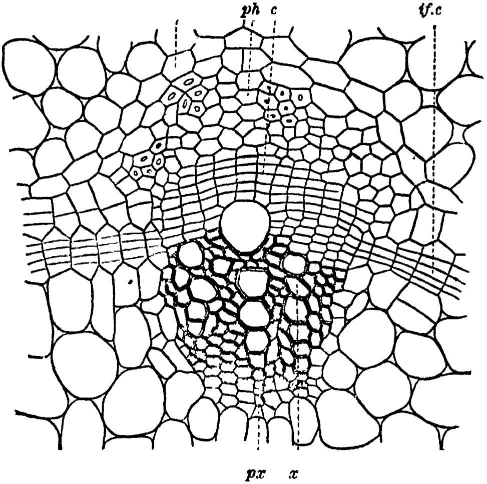


Fig. 738. Collateral bundle of *Ricinus*. *en.* Endodermis. *ph.* Phloëm *c.* Cambium. *px.* Protoxylem. *x.* Xylem. *if.c.* Interfascicular cambium.

Differentiation of the Bundles.

The transformation of the procambium merismatic cells into the permanent tissue of the vascular bundle does not take place all at once, but begins at definite spots and extends in a regular manner from those points. In the first type of collateral bundle described above, the development of wood starts by the differentiation of a spiral or annular vessel or row of tracheïds situated, with few exceptions, at the apex of the wedge, forming the *protoxylem* (*fig.* 738, *px*). This is the only point at which spiral or annular vessels ever occur in such a bundle. The differentiation then proceeds gradually backwards or centrifugally, forming the *primary* wood, which consists of vascular and parenchymatous elements with thickened lignified walls. The vessels and tracheïds are variously pitted, as already described, and they lose their protoplasmic contents.

The outer part or bast of this type of bundle begins to be differentiated at a place at the exterior of the wedge-shaped mass, where a few sieve tubes and their companion cells may be observed. These constitute the *protophloëm*. Their shape becomes altered by pressure within the bast; their walls appear swollen and their cavities almost indistinguishable. The differentiation of the rest of the bast proceeds then centripetally towards the wood. In some cases the wood and bast come to meet as above described; in others a band of the procambium

FIG. 739.

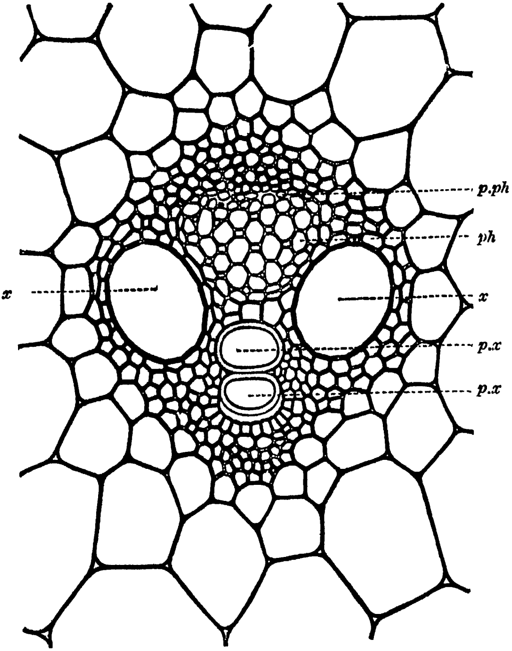


Fig. 739. Collateral bundle from stem of a Monocotyledon. *ph.* Phloëm. *x.* Xylem vessels. *p.x.* Protoxylem. *p.ph.* Protophloëm. The bundle is surrounded by a small-celled sheath of sclerenchyma. After Kny.

between them does not become permanent tissue, but retains its merismatic powers. This constitutes the *cambium* of the bundle (*fig.* 738, *c*). Its cells are usually elongated parenchyma with thin walls and granular protoplasm. By this merismatic layer the bast on the one side and the wood on the other are increased, so that the conjoint bundle grows both inwards and outwards. This *fascicular* cambium is a primary meristem.

FIG. 740.

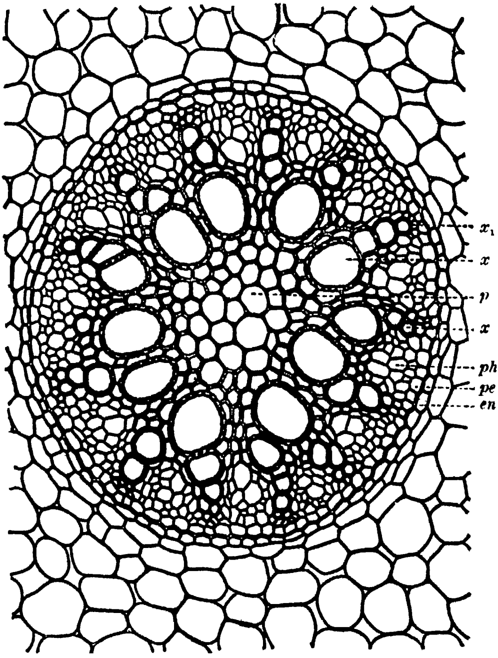


Fig. 740. Section of stele of root. After Kny. *en.* Endodermis. *pe.* Pericycle. *x.* Xylem bundles, the protoxylem, x_1, abutting on the pericycle. *ph.* Phloëm bundles alternating with the bundles of xylem. *p.* Pith, or conjunctive tissue of the stele.

The collateral bundle of the second type is similarly developed from the procambium strand. The protoxylem is an annular or spiral vessel of some size, occupying a position in the front of the bundle. Frequently it abuts on a lysigenous intercellular space, as seen in *fig.* 739. The protophloëm, again, lies at the back of the bast; there is no cambium left between the bast and wood.

In the concentric bundle both protoxylem and protophloëm can be identified. If the section of the bundle be circular, the protoxylem lies at the centre of the circle (*fig.* 733). In concentric gamodesmic bundles there may be several groups of protoxylem. These arise in some cases on the periphery of the xylem strand, as in some Selaginellas and Ferns; in some other Ferns they are situated more internally (*fig.* 734). The protophloëm arises at one or more points on the outside of the circumferential zone of bast.

In radially arranged bundles each strand of procambium becomes completely converted into either wood or bast. The position of both protoxylem and protophloëm in these is always external (*fig.* 740), so that the differentiation of the primary wood is centripetal instead of centrifugal, as in the collateral bundles.

This difference of direction of formation of the primary wood is one of the most important anatomical differences between the stem and the root of a phanerogamic plant.

CHAPTER IV.

THE STRUCTURE OF THE STEM.

DICOTYLEDONOUS TYPE.

As we have already indicated, the stem shows considerable variation in its structure, dependent chiefly upon the arrangement of the vascular tissue in the stele. In the great majority of forms the stem is monostelic, and its tissues are arranged on one of two plans, leading to recognition of the two types especially characteristic of Dicotyledons and Conifers on the one hand, and Monocotyledons on the other.

FIG. 741.

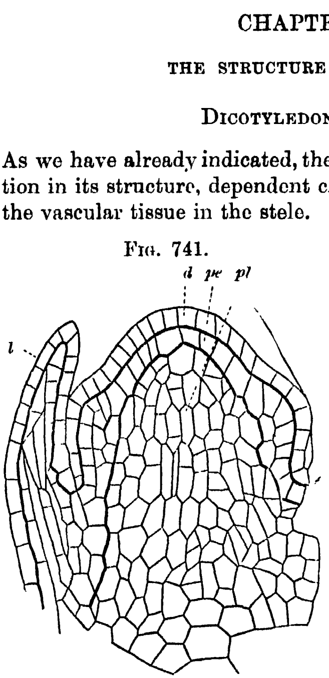


Fig. 741. Growing point of the stem of a Dicotyledon. After Douliot. *d*. Dermatogen. *pe*. Periblem. *pl*. Plerome. *l*. Young leaf. The thick lines are exaggerated to show the limits of the three regions.

The dicotyledonous stem in its very young condition shows us in a longitudinal section of its apex a meristem of small cells, usually displaying dermatogen, periblem, and plerome (*fig*. 741). A little way behind the apex the plerome can be seen in transverse sections to be marked off more or less distinctly by the innermost layer of the periblem.

The epidermis consists of a sheet of cells with cuticularised external walls, closely attached to each other, and having no intercellular spaces except the stomata, of which it bears a considerable number. The cells are usually empty save for the presence of water, except in aquatic plants, when they contain chloroplasts. These stems have no stomata. Frequently the epidermis is provided with hairs of various shapes, and occasionally secreting cells are found among the others. The hairs, too, are often glandular.

The cortex consists typically of parenchyma, with numerous intercellular spaces. The outer layers frequently contain chloroplasts, starch grains, &c. Bands, sheaths, or isolated patches of sclerenchyma are often present. The innermost layer constitutes a sheath round the stele, named the *endodermis* (*fig.* 742, *en*), which is sometimes conspicuous, but generally very difficult to identify. It can sometimes be recognised by its cells being crowded with starch grains.

FIG. 742.

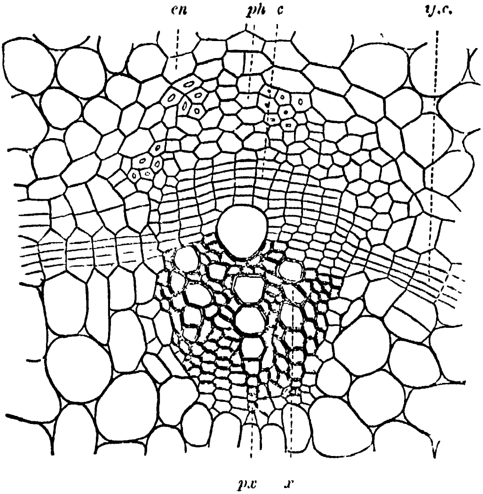


Fig. 742. Collateral bundle of *Ricinus*. *en*. Endodermis. *ph*. Phloem. *c*. Cambium. *px*. Protoxylem. *x*. Xylem. *i.f.c*. Interfascicular cambium. After Sachs.

The cortex often increases along longitudinal lines, making the stem *ribbed*, or in isolated spots, producing *emergences* or *prickles*. Both ribs and prickles are covered by epidermis.

The epidermis and cortex persist throughout the life of herbaceous stems, but in those which increase much in thickness both are ultimately replaced by *bark*.

Not far from the apex of the stele the procambium bundles become differentiated, and in transverse section are seen to be

FIG. 743.

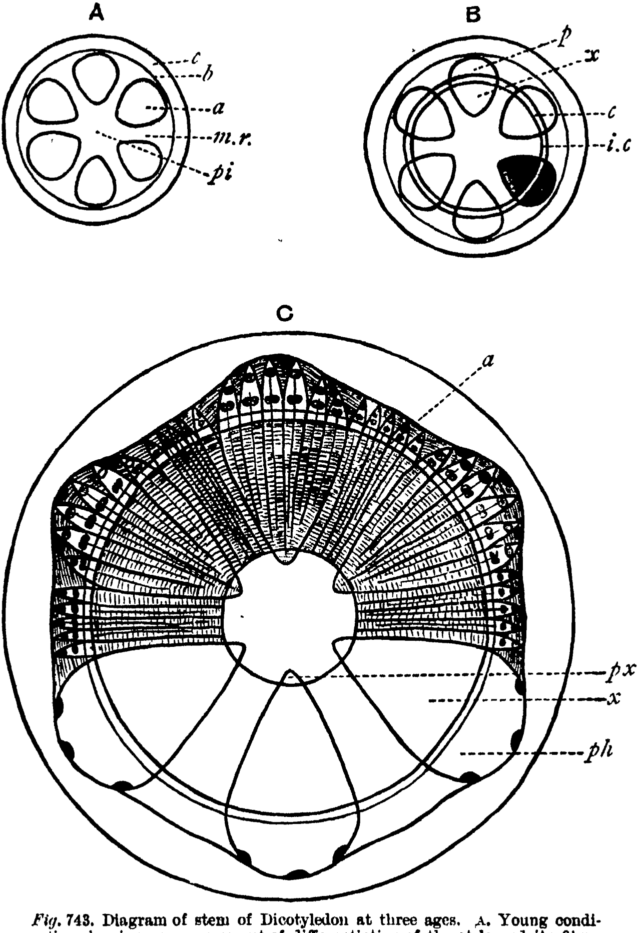


Fig. 743. Diagram of stem of Dicotyledon at three ages. A. Young condition showing commencement of differentiation of the stele and its fibro-vascular bundles. *a*. Procambium bundles arising in *b*, the stele. *c*. Cortex. *m.r.* Medullary ray. *pi*. Pith. B. A little older stage. *p*. Phloëm. *x*. Xylem. *c*. Fascicular cambium. *i.c.* Interfascicular cambium. One of the bundles has been shaded. C. Older stage after the commencement of secondary thickening. *px*. Protoxylem. *x*. Secondary wood. *ph*. Secondary bast. *a*. New bundles formed by the interfascicular cambium in the primary medullary rays. The secondary medullary rays are indicated by the black radial lines in the bundles. After Sachs.

arranged in a ring surrounding a central pith. They are separated by conjunctive ground tissue, strands of which extend from the pith to the circumferential pericycle. These strands constitute the primary medullary rays. As they get older the differentiation of the vascular bundles from the procambium takes place, the protoxylem lying next the pith, and the protophloëm abutting on the pericycle. The bundles of such a stem are collateral. When they are numerous, and consequently close together, the protoxylems form a more or less evident ring round the pith, and constitute the so-called *medullary sheath.*

The differentiation of the vascular elements does not usually extend throughout the bundle, but a narrow layer of meristem is left between the bast and wood, the *cambium* (*fig.* 742, *c*).

This meristem forms new wood and bast by repeated divisions of a single layer of cells, the wood upon its interior, the bast upon its exterior surface. Through the activity of the cambium, therefore, the individual bundles grow in a radial direction. The divisions of the cambium are chiefly tangential in direction, but radial ones also take place, as the cambium becomes pressed towards the exterior of the stem by the accumulation of the wood it is continually forming. The bundle thus becomes broader as well as longer, as seen in transverse section.

Soon after the differentiation of the primary bundles is complete, changes take place in certain cells of the medullary rays, which become merismatic and form a band of cambium across the rays. This always occurs between the cambiums of the contiguous bundles, so giving rise to a ring of cambium round the stem at that point. The portion of the ring which is formed in the rays, and which differs from the rest by being a *secondary* meristem, is known as the *interfascicular* cambium (*fig.* 742, *if.c.*). The interfascicular cambium not only forms new parenchymatous tissue in the ray, maintaining its existence, but part of it forms also new wood and bast like the cambium of the bundle. We may get new vascular bundles intercalated in this way between the original ones, or we may have the latter continually increasing in breadth, their number remaining constant. When new bundles are thus formed they can be distinguished in the stem by not possessing any protoxylem, and by not being continued outwards into the leaves as are the primary ones.

New medullary rays or radial bands of parenchyma are formed in the substance of the bundles by the cambium as the mass of wood increases, which are known as *secondary* medullary rays. They differ from the primary ones not only in this mode of origin, but also by not extending to the pith on the one hand or to the pericycle on the other. Their extent in a vertical direction also varies considerably in different cases.

The medullary rays, both primary and secondary, usually widen out in the bast in consequence of the stretching of the tissue brought about by the continuous increase of the central mass of wood. This leads to radial divisions of the cells of the medullary rays towards their outer ends.

The cells formed by the cambium undergo similar transformations to those of the procambium. The tissue of the two meristems is somewhat different, however, the procambium cells being elongated and narrow with square ends, while those of the cambium are prismatic. The behaviour of the two is different, the divisions of the procambial cells taking place in three planes, those of the cambium chiefly tangentially, but to a slight extent radially as well.

The activity of the cambium is greater towards the interior of the stem than outwards, so that much more wood is formed than bast.

The cells when first cut off from the cambium are thin-walled and hardly distinguishable from the merismatic cells. Gradually they become changed to the permanent form. Those which are to form xylem parenchyma divide transversely, becoming cubical instead of prismatic. Those destined to be tracheids or segments of vessels increase considerably in diameter, displacing and compressing the adjacent cells. They thicken regularly or irregularly, as before described. The fibres which originate from the cambium exhibit a curious mode of growth, their upper and lower ends, which are, like those of the cambial cells, somewhat pointed, growing past those of the cells above and below them, which behave similarly. Thus the separate fibres extend themselves between their neighbours, and often attain considerable length. Their transverse diameter does not increase as in the case of the vessels. This mode of behaviour is known as *sliding growth*. It is seen not only in the young stem, but often in cases where growth in thickness is not accompanied by growth in length, when it causes curious displacements of the tissues.

In the Conifers the secondary wood formed by the cambium consists of fibrous tracheids whose radial walls are furnished with bordered pits (*fig.* 638).

The cells of the secondary bast include chiefly parenchyma and sieve tubes. The latter show a little peculiarity in their development, whether from cambium or procambium. The segment of the merismatic cell which is about to give rise to a sieve tube cuts off by longitudinal walls one or sometimes two segments, which are much smaller than the remaining one. These constitute the companion cells (*fig.* 744, *c*); each remains filled with protoplasm and contains a large nucleus. The remaining cell slightly thickens its end walls, which become perforated, forming sieve plates, through which the contents of the adjacent cells communicate (*fig.* 744, *s.p.*). The nucleus breaks up and disappears, so that the mature sieve tube has not a nucleus. The sieve plates have later a deposit of callus upon them, which also lines the perforations.

FIG. 744.

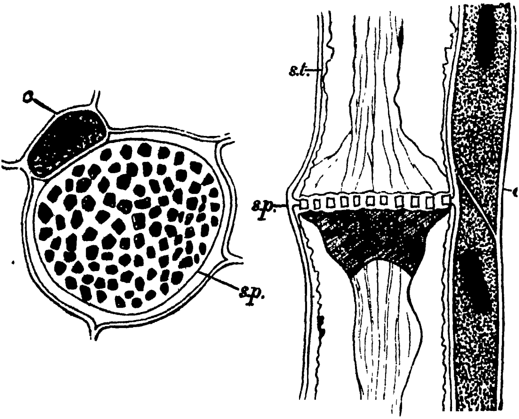


Fig. 744. Sieve tube and companion cells. *s.t.* Segment of the sieve tube. *s.p.* Sieve plate. *c.* Companion cells. × 540. After Strasburger.

In Gymnosperms the sieve tubes have no companion cells.

The cambium cells, though usually elongated prisms in shape, are not always so. Those cells which continue the primary medullary rays (*fig.* 742, *if.c.*), or which form secondary ones, divide transversely, becoming almost cubical. The segments which they contribute to the medullary rays have thus always this shape.

By this mode of behaviour of the cambium ring, wood is continually formed centrifugally, and the stem increases in thickness. The activity of the cambium continues for the greater portion of each year, ceasing only during the winter, and consequently a new zone of wood is produced annually. As the year advances, the amount of new wood formed causes more and more compression within the bundle, so that the diameter of the new vessels gradually becomes smaller and smaller. Those that are formed in autumn have consequently much

FIG. 745.

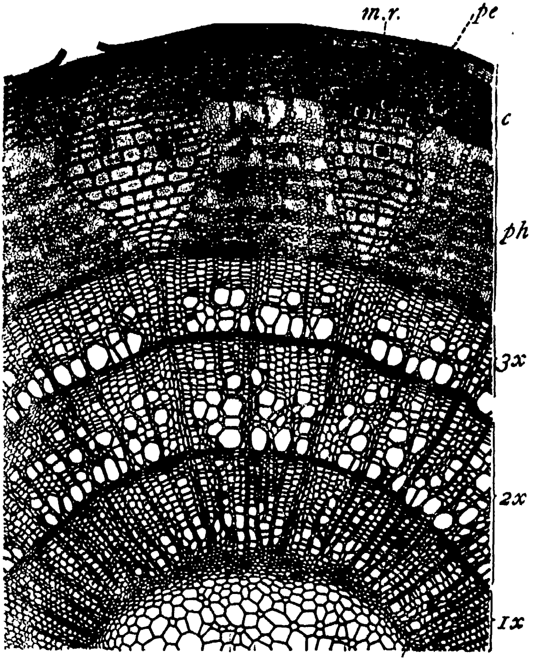


Fig. 745. Section of twig of Lime, three years old. 1x, 2x, 3x. The successive annual rings of wood. *ph.* Phloëm. *c.* Cortex. *m.r.* Primary medullary ray. *pe.* Layer of periderm. After Kny.

smaller diameters than those of the next year's spring wood, for the tension becomes relieved during the winter by the splitting of the external layers of the trunk through frost, so that the extent of each year's formation is usually very evident. The successive zones of wood are known as *annual rings* (*fig.* 745).

The activity of the cambium on its external face is marked by a similar intermittence. Usually, however, the limits of each year's formation of bast are not distinct. The bast is further much interfered with by secondary formations of periderm.

In an old stem the internal zones of wood are often very different in appearance from the more external ones. As the wood gets older the cells lose their protoplasm and die, becoming hard and dry, and frequently much darker in colour. The outer zones, on the contrary, contain cells which are living, and which are charged with water. The secondary wood can thus be divided into the *alburnum* or *sapwood*, and the *duramen* or *heart-wood*.

FIG. 746.

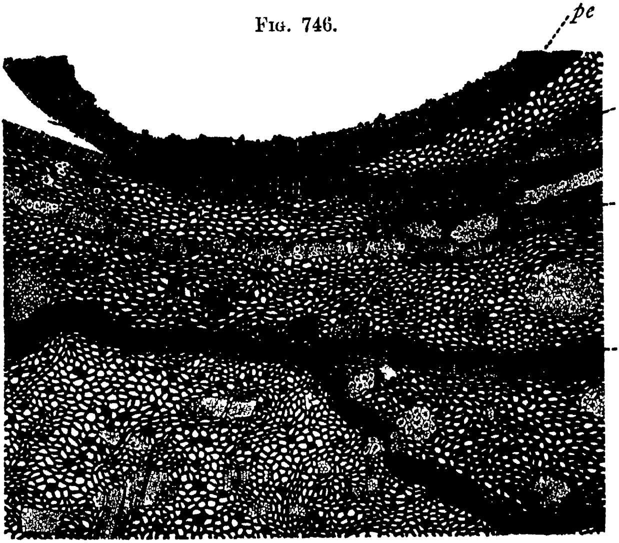


Fig. 746. Section of bark of *Quercus sessiliflora*. After Kny. *pe*. Periderm layers, arising at different depths in the cortex.

The increase in thickness of the stem thus brought about sets up great and gradually increasing tension in the cortex, leading to early rupture of the epidermis. To replace the latter such stems show a continual formation of layers of phellogen, each giving rise to a cork layer externally, and generally to phelloderm or secondary cortex internally. This takes place usually at a very early date immediately below the epidermis. The periderm so formed being impervious to moisture, all the cells external to it dry up and perish. Successive layers of phellogen arising continually deeper and deeper in the cortex cause the external dry tissue to be very complex in structure. The phellogen layers often extend as far internally as the secondary bast. The mass of external tissue thus formed is known as the *bark*. It includes all the layers of periderm, with varying quantities of cortical tissue, pericycle, and bast. It is consequently extremely complex. The phellogens often form not only ordinary cork cells, but mixed with them cells thickened sclerenchymatously.

In some cases the bark is the product of a single phellogen which continues its activity for many years. A very thick external layer of cork is thus formed, as in the cork oak. In other cases a new phellogen is formed every few years, deeper in the tissue than the previous one.

These formations of phellogen may be cylindrical, cutting off regular zones or cylinders of tissue. Frequently, however, they dip into the other tissues somewhat irregularly, and often intersect each other, giving rise to the separation from the stem of irregular sheets of bark (*fig.* 746). These sometimes, as in the Plane tree, are shed from the trunk in large patches. We distinguish the latter case from the former by the terms *scale* bark and *ringed* bark respectively. Ringed bark is generally ruptured longitudinally somewhat irregularly, and presents the appearance of grooves or furrows, often of considerable depth.

Besides this formation of bark, serving as a normal protection to the internal tissues, another tissue is developed in cases where an injury occurs to woody plants. This is known as *callus*, and consists of ordinary parenchyma, which ultimately becomes covered with cork. It is only peculiar in its mode of origin, the cells which are adjacent to the injured ones becoming merismatic. There is not much difference between this formation and that of the covering of exposed surfaces by cork as already described (page 332). If in a stem or root the wound extends to the cambium, the callus originates at its sides as before, but cork and new cambium are formed in it, the latter joining the cambium which was injured, and growing over and closing the wound. If any object becomes impacted in the wood by the injury, the new formation grows over it and completely encloses it.

Turning from transverse sections to study the structure as revealed by longitudinal ones, this type of stem shows at the summit a small-celled meristem, as already described, forming a conical apex on which small lateral protrusions arise in acropetal succession. The division into nodes and internodes is visible at a very early period, the small protrusions or cushions arising at the former. Each protrusion is the rudiment of a leaf with a young bud or branch in its axil. It consists of a small outgrowth of the periblem covered by the young epidermis. The plerome or central portion of the stem does not contribute to its formation.

A little further from the apex the differentiation of the procambium bundles in the stele can be seen. By the time this is evident the leaves have elongated to a greater extent, and the differentiation of their internal tissue is progressing. Each procambium bundle of the stele is found to be continuous with one of those of the leaf, so that the bundle appears to originate in the leaf and to pass downwards into the stem. It is said on this account to be a *common* bundle, that is, common to leaf and stem. The first appearance indeed of protoxylem is usually seen near the point of junction of the two members. These primary common bundles are known as *leaf-trace* bundles on account of their origin as described.

FIG. 747.

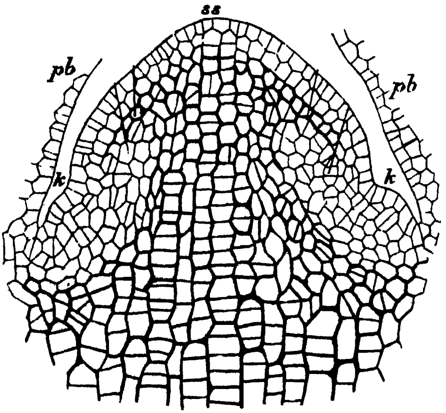


FIG. 748.

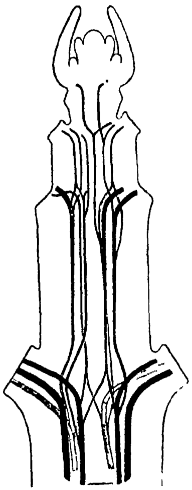


Fig. 747. *Phaseolus multiflorus.* Longitudinal section through the apical region of the stem of an embryo. *ss.* Apex. *pb*, *pb*. Parts of the two first leaves. *k*, *k*. Commencement of their axillary buds. After Sachs.—*Fig.* 748. Diagram of course of bundles in stem of Dicotyledon. After Nacgeli.

Following these leaf-trace bundles down the stem, they are found to pass independently through the internodes, joining at the nodes other bundles entering there from the leaf vertically below them, or bifurcating and joining those entering the stem from the orthostichies next in order. If a leaf sends many bundles into the stem, their courses become complicated; they sometimes join the other primary bundles of the stelar ring, or less frequently they form also independent circles in the cortex or the pith.

Fig. 749.

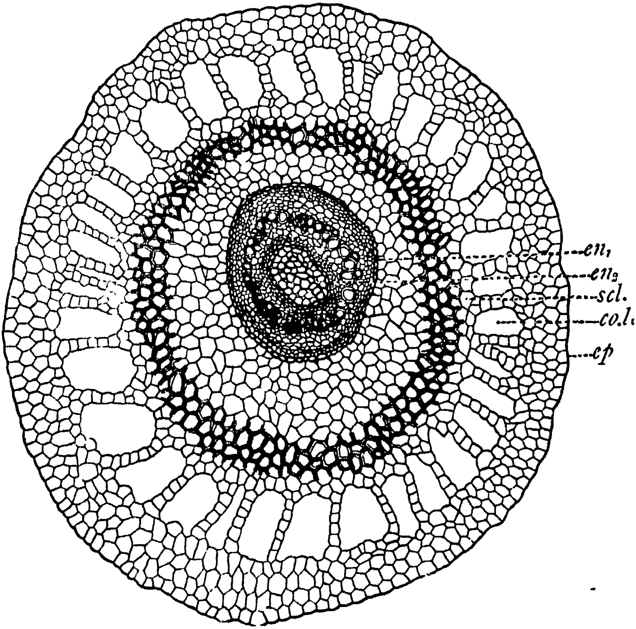


Fig. 749. Aquatic stem of *Marsilea*. *ep.* Epidermis. *co.la.* Cortical lacunæ. *scl.* Sclerenchyma in the cortex. en_1. Outer; en_2. inner fused endodermis of the steles. The steles are fused together-laterally, forming a vascular ring in the centre of the stem surrounding a small portion of the ground tissue.

The secondary bundles formed by the cambium have no connection with the leaves; they are *cauline* bundles only.

The branches of the stem arise, as we have seen, in the axils of the leaves by development there of lateral growing points which arise as small protuberances on the side of the main one (*fig.* 747). They arise only from the periblem and the epidermal layer, as do the leaves in whose axils they occur. As they develop, their structure is found to be similar to that of their parent; they show the same merismatic layers, each of which becomes continuous with the corresponding layer of the latter.

In aquatic stems, both of this and of the monocotyledonous type and of certain Cryptogams, there is comparatively little development of wood. Instead, the cortex is unusually large, and frequently shows lacunæ or air-passages, which occupy a considerable part of its substance, very few rows or chains of cells separating them (*fig.* 749). In some cases the cells abutting on these air-passages are developed into hairs of curious form. These lacunæ are interrupted at the nodes, where the parenchyma is continuous.

MONOCOTYLEDONOUS TYPE.

The structure of the growing point of stems of this type differs slightly from that of the former one. The apex is

FIG. 750.

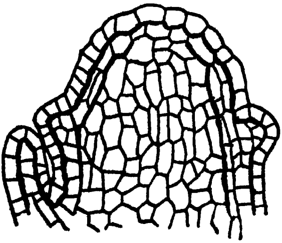


FIG. 751.

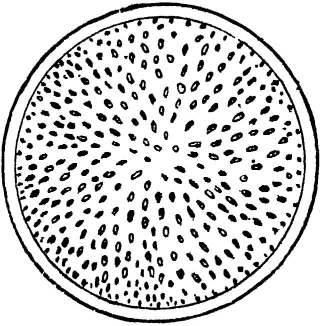


Fig. 750. Growing point of stem of monocotyledonous plant. The thickness of the cell-walls at the limits of the dermatogen and periblem is exaggerated for the purpose of distinction. After Douliot.——*Fig.* 751. Diagram of monocotyledonous stem, showing bundles scattered more or less irregularly in the stele.

covered by a dermatogen, within which are the periblem and plerome, but the distinction between the latter two is not well marked, a single initial layer being probably common to both (*fig.* 750).

A transverse section taken a little lower down shows the central stele differentiated as in the former case. The arrangement in the stele is, however, very different. Instead of a ring of procambium bundles arranged round a central pith, many bundles are found, arranged more or less in a number of rings, and all pointing to the centre of the stele. Those first formed lie towards the centre of the cylinder, and later others appear nearer the periphery. Further development leads to increasing irregularity in the ring-like arrangement, so that in an older stem the bundles seem to be scattered irregularly in the cylinder (*fig.* 751). In a few cases, as in the Rushes, there is a single

FIG. 752.

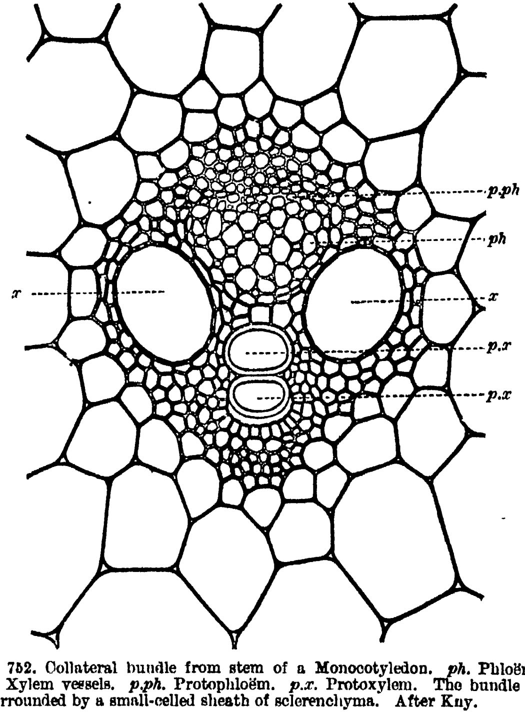


Fig. 752. Collateral bundle from stem of a Monocotyledon. *ph.* Phloëm. *x.* Xylem vessels. *p.ph.* Protophloëm. *p.x.* Protoxylem. The bundle is surrounded by a small-celled sheath of sclerenchyma. After Kny.

or at most a double ring of bundles close to the periphery and surrounding a very large central pith.

The bundles are of the collateral type, but as differentiation of the tissues proceeds, all the procambium is transformed into permanent tissue, so that the bundles are *closed*, containing no cambium. The protoxylem is at the front of the bundle, and consists of one or two spiral or annular vessels (*fig.* 752, *p.x*). The large ducts or vessels on the wings of the bundle are next developed and then the remainder of the wood. The protophloëm is at the back of the bust (*fig.* 752, *p.ph*). The whole bundle is surrounded by a sheath consisting of a few layers of sclerenchyma belonging to the conjunctive tissue of the stele.

FIG. 753.

FIG. 754.

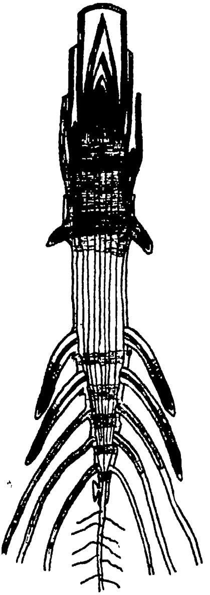


FIG. 755.

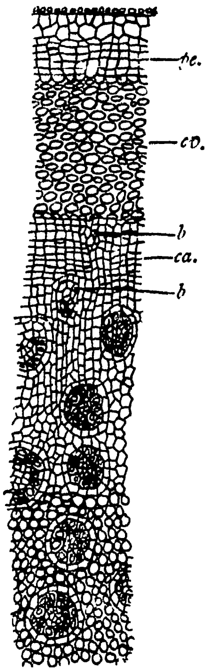


Fig. 753. Diagram of course of bundles in the stem of a Monocotyledon (Palm).——*Fig.* 754. Diagram of mode of growth of stem of Monocotyledon (*Zea Mays*). After Sachs.——*Fig.* 755. Part of a section of stem of *Dracæna*. *pe.* Cork. *co.* Cortex. *ca.* Cambium layer. *b*, *b*. Bundles in course of formation.

Viewed in longitudinal section the bundles are seen, as in the other type, to be common bundles, being continuous with those which belong to the leaves. Usually there are several bundles in each leaf. In the simplest type each can be traced inwards for some distance, after which its course gradually curves outwards, proceeding obliquely down the stem; it ultimately joins a bundle coming from a lower leaf (*fig.* 753).

In most grasses, in consequence of the great and rapid elongation of the internodes, the bundles appear to lie perpendicularly in the stem. They do not extend far towards the centre of the stele, which becomes hollow. At the nodes the bundles anastomose freely with each other, forming a number of diaphragms across the cavity.

The pericycle or external portion of the stele is sometimes lignified, and forms a hard sheath to the cylinder. Its cells are chiefly fibrous, serving, with the sclerenchymatous sheaths to the separate bundles, to give the necessary rigidity to the stem. The cortex of the stem varies a good deal in thickness, being generally thin in sub-aerial and relatively thick in subterranean ones.

No cambium being present in this type of stem, there is no regular increase of thickness as in the former type. The stem of the young plant is at first very slight, but as growth proceeds the growing point becomes continually larger and more vigorous, so that each node and internode become larger than the preceding ones. The young stem has thus the form of an inverted cone (*fig.* 754). After a time this continuous enlargement ceases, and the upper portion of the stem is cylindrical.

This kind of stem is not associated, as is the former type, with a tap root. The primary root soon disappears, and the further root system consists of its branches and a number of adventitious roots developed from the lower part of the stem.

In some Monocotyledons, e.g. *Dracæna*, *Yucca*, a regular growth in thickness of the stem occurs. It is brought about by the development of a secondary meristem or cambium layer several cells thick, which arises towards the exterior of the cylinder (*fig.* 755). This forms a series of bundles gradually proceeding outwards. These bundles are sometimes concentric, having their bast internal.

In such stems there is a formation of periderm in the cortex, which is provided with lenticels.

OTHER TYPES OF STEM.

Besides the two types of monostelic stems described, another is found in some of the Vascular Cryptogams. The general features of the cortex vary a good deal, stereomic tissue being distributed in many ways. A special feature of the stele is that the development of the xylem is centripetal. The xylem and phloëm bundles are placed side by side, and thus alternate with each other. The structure is seen best in the stem of *Lycopodium* (*fig.* 756). The stele is clothed by a pseudo-pericycle and surrounded by an endodermis, both of which are developed from the cortex. At various distances round the ring of pericycle, touching its internal face, a number of protoxylem groups are differentiated, between which are an equal number of protophloëms. The primary wood develops centripetally

FIG. 756.

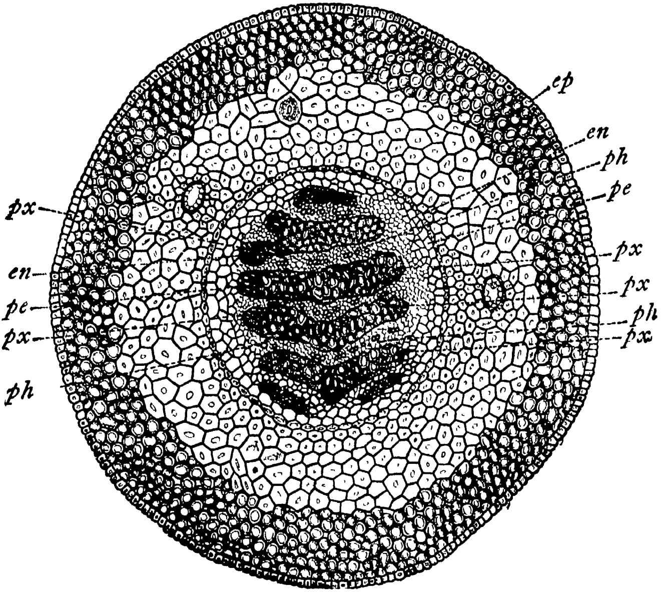


Fig. 756. Section of stem of *Lycopodium*. *ep*. Epidermis. *en*. Endodermis. *pe*. Pseudo-pericycle. *px*. Groups of protoxylem. *ph*. Phloëm. After Sachs.

from these protoxylem groups, and the separate masses so formed unite irregularly in the centre of the stele, forming a number of bands which are separated by similar bands of phloëm. A somewhat similar type of structure is found also in *Psilotum* and a few other plants.

FIG. 757.

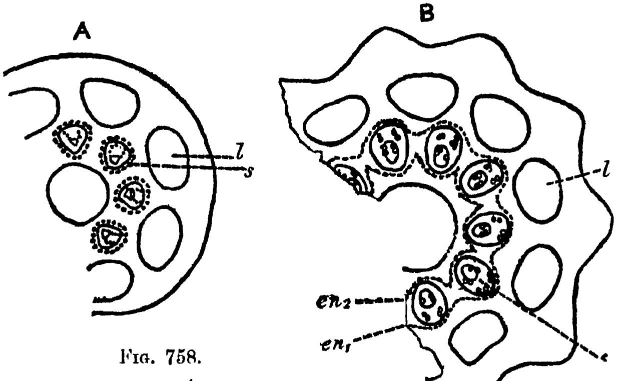


FIG. 758.

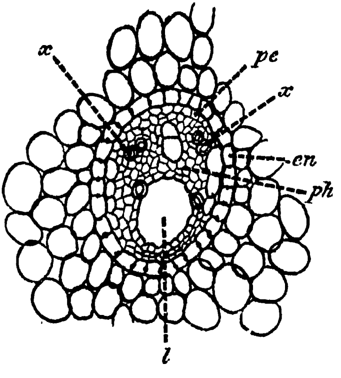


Fig. 757. Diagram of stem in two species of *Equisetum*. A. *E. limosum*. *s*. The separate bundles or schizosteles, each with its endodermis. B. *E. hiemale*. The schizosteles, *s*, have their endodermis fused laterally. In both figures *l* = cortical lacunæ. After Pfitzer. *Fig.* 758. Section of vascular bundle of *Equisetum limosum*. *en*. Endodermis. *pe*. Pericycle. *x*. Xylem. *ph*. Phloëm. *l*. Lacuna. After Dippel.

A similar centripetal formation of the primary wood is found in the separate steles of several of the polystelic Selaginellas, and also in the hypocotyledonary portion of the axis in some of the Phanerogams, where the transition from the structure of the stele of the stem to that of the root can be observed.

Schizostelic Stems.—In this type of stem the central stele can be observed at its lower part, but as the axis is examined higher up, the cylinder is found to break up into as many strands as there are vascular bundles, and these separate from each other, each becoming clothed with its own pericycle and endodermis, continuous below with those of the original monostele. The separate bundles may be scattered through the substance

FIG. 759.

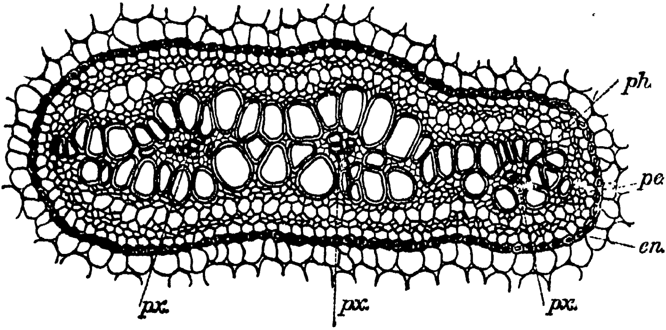


Fig. 759. Stele of stem of Fern (*Polypodium*), composed of three fused concentric bundles. *en.* Endodermis. *pe.* Pericycle. *ph.* Phloem. *px.* Groups of protoxylem.

FIG. 760.

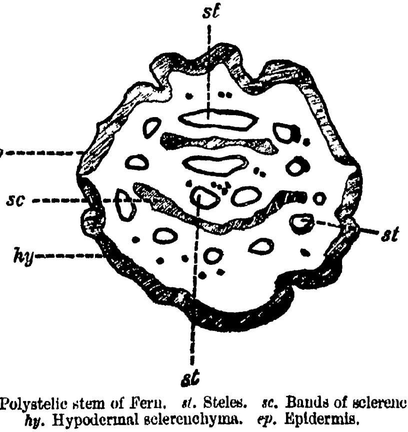


Fig. 760. Polystelic stem of Fern. *st.* Steles. *sc.* Bands of sclerenchyma. *hy.* Hypodermal sclerenchyma. *ep.* Epidermis.

of the stem, or may be arranged in a circle. At intervals they anastomose with each other, forming a network of bundles. This is due to a varying and irregular differentiation of the tissue of the plerome.

This type of arrangement is rare among flowering plants, but it is not uncommon among the Cryptogams, being very frequently found among the *Equisetaceæ*. Some species of the latter show the separate bundles arranged in a ring, each with its pericycle and endodermis surrounding it (*fig.* 757, A); other species show the separate bundles all fused together laterally, except that part of their pericycle remains between each pair. The endodermis and part of the pericycle disappear from between them, but

FIG. 761.

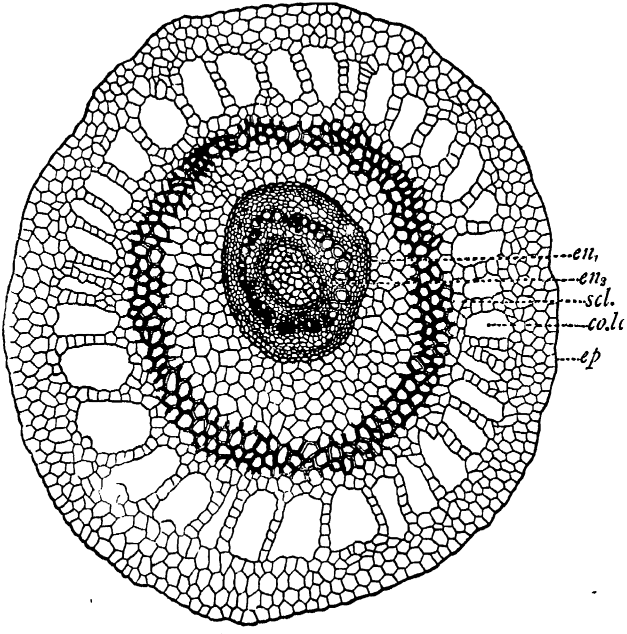


Fig. 761. Gamostelic stem of *Marsilea*. *ep.* Epidermis. *co.la.* Cortical lacunæ. *scl.* Sclerenchyma in the cortex. en_1. Outer; en_2. inner fused endodermis of the steles. The steles are fused together laterally, forming a vascular ring in the centre of the stem surrounding a small portion of the ground tissue.

remain fused in front and behind them, giving the appearance of an internal and external sheath (*fig.* 757, B). In some cases the inner endodermis is almost or entirely indistinguishable, when the structure simulates a monostele. The separate bundles of the Equisetums are peculiar in having a large lacunar space in the region of the xylem, causing the latter to be represented by only a few vascular elements (*fig.* 758).

The bundles in schizostelic stems are always collateral.

Polystelic Stems.—In these as in the last described type the first-formed stem is monostelic, but as it grows the differentiation of the tissue of the plerome becomes irregular giving rise to several steles separated by conjunctive tissue (*fig.* 760). Each stele is clothed by pericycle and endodermis. The latter layer differs from the endodermis of the monostelic stem in that the origin of part of it at any rate takes place in the plerome and not the periblem. Each stele contains usually more than one vascular bundle (*fig.* 759). The separate xylems of these steles are fused together, so that there is no pith. The separate steles may be irregularly disposed through the thickness of the stem, or they may be arranged in a more or less ring-like manner. In the latter case the central tissue must not be confused with the pith of a monostelic stem. The separate steles frequently anastomose with each other, forming an irregular network which can readily be seen after destruction of the soft tissues by maceration. Two varieties of the arrangement occur. In the first, which is known as *dialystely*, the steles remain for the most part independent, so that a transverse section shows them separate or fused two or three together (*fig.* 760). In the second the steles are arranged in a ring, and are close together. Many of them fuse together laterally, giving the appearance of an almost complete ring of vascular tissue, simulating the appearance often of the ring of collateral bundles of the dicotyledonous type of monostelic stem. As they fuse, the endodermis and pericycle on their lateral faces disappear, and the parts of those layers behind and in front of them become continuous. The ring of tissue can be distinguished from the ring of the dicotyledonous stem by the

FIG. 762.

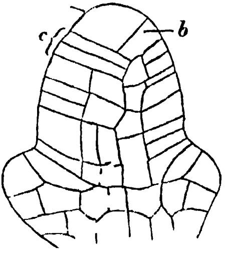


Fig. 762. Growing point of shoot of *Equisetum arvense*. × 250. *a.* Apical cell. *b*, *c*. Successive segments cut off from it.

presence of internal endodermis, pericycle, and phloëm layers (*fig.* 761).

This mode of arrangement, known as *gamostely*, is met with in certain Ferns, especially *Marsilea*, and in some species of *Auricula* among Phanerogams.

The conjunctive tissue in both polystelic and schizostelic stems is partly derived from the periblem and partly from the plerome. Their growing points are generally furnished with an apical cell (*fig.* 762, *a*), though sometimes they have a small-celled meristem.

CHAPTER V.

THE STRUCTURE OF THE ROOT.

UNLIKE the stem, the root in the Phanerogams always arises in the interior of the tissue of the embryo. In the young embryo, whose formation was spoken of in connection with the seed (page 228), the lower apex is covered by the suspensor. The first root arises at the junction of the two, at least one cell of the suspensor taking part in its formation, as will be described

FIG. 763.

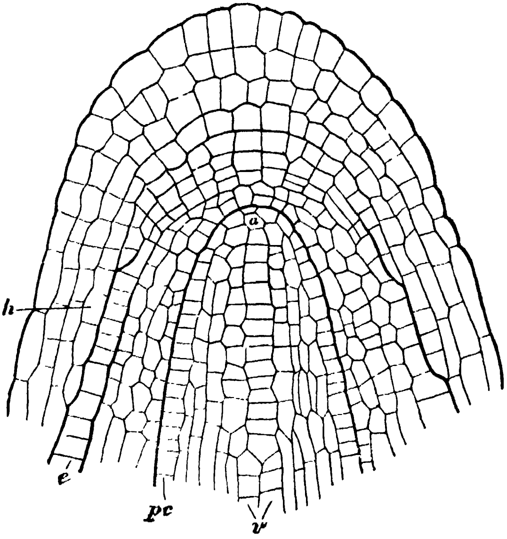


Fig. 763. *Polygonum Fagopyrum.* Root apex, median longitudinal section. *a.* Apical meristem. *pc.* Pericycle, outside boundary of the plerome. *v.* Rudiment of a vessel. *e.* Dermatogen. Between *pc* and *e*, periblem. *h.* Root-cap. After De Bary.

later. The apex of the root consists of a mass of merismatic tissue in which the dermatogen, periblem, and plerome can be distinguished. The separate histogenic layers are frequently more distinct than in the case of the stem. The dermatogen divides into a number of layers, the outermost of which form a many-layered epidermis known as the root-cap (*fig.* 763, *h*). In most Dicotyledons the innermost layer is continued backwards over the surface, and forms the so-called *piliferous layer.* In most Monocotyledons the dermatogen does not persist far from the apex, and the external layer above the point of its disappearance is the outer layer of the periblem. This external layer, whatever its origin, is known as the *epiblema*, and the special absorbent structures of the root, the *root-hairs*, are developed from it (*fig.* 711).

The periblem of the root gives rise to a cortex which persists for a longer or shorter time. Its cells are generally parenchymatous with thin walls, and there are many intercellular spaces among them. The hypodermal layer is known as the *exodermis*, and its cells are frequently thickened as already described (*fig.* 718). The endodermis is well marked, and its cells are usually thickened considerably. When, as in *Iris florentina*, the thickening is regular round the internal and radial walls, there are certain cells, the *passage* cells, left unthickened (*fig.* 764, *p.c.*). Very frequently the thickening is deposited in the form of the band described at page 828, the separate thick portions somewhat resembling the projections of a cogged wheel (*fig.* 765). The thickenings are cuticularised in both cases. In *Equisetum* the endodermis is two layers of cells thick.

FIG. 764.

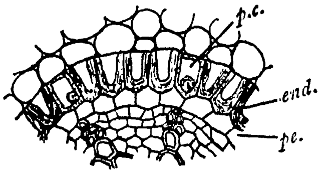


FIG. 765.

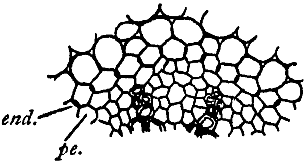


Fig. 764. Endodermis and pericycle of root of *Iris florentina*. *end.* Endodermis. *p.c.* Passage cell. *pe.* Pericycle.——*Fig.* 765. Endodermis of root with cogged thickening.

The stele or central cylinder differs in many importan particulars from that of the stem. The pericycle is usually onl; one layer of cells in thickness, though in the Gymnosperms an(

some few Dicotyledons it is many-layered. It is absent from the roots of *Equisetum.* Its cells are parenchymatous; it does not show so much differentiation as it does in the stem, rarely containing, when more than one layer of cells thick, any additional form of tissue except secretory ducts. When thickening of the roots occurs it gives rise to certain merismatic layers which take an important share in the process. The vascular bundles vary in number, but the bast and the wood are never conjoined; they lie side by side with each other, on separate radii of the axis with a little conjunctive tissue between them. They are first noticeable as procambium strands, and gradually take on the form of their permanent tissue. In the differentiation of the

FIG. 766.

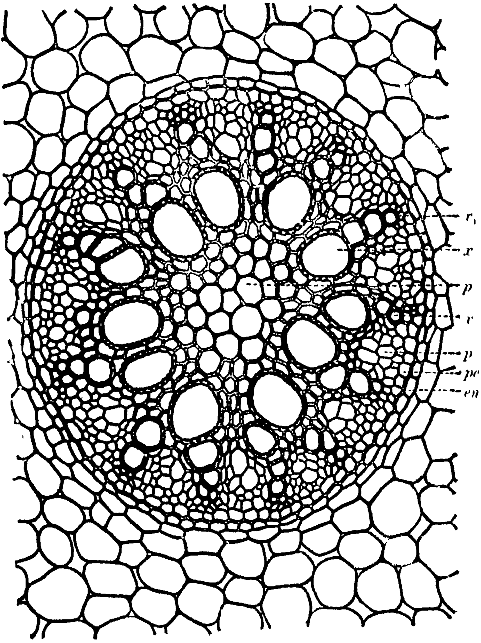


Fig. 766. Section of stele of root. After Kny. *en.* Endodermis. *pe.* Pericycle. *x.* Xylem bundles, the protoxylem, x_1, abutting on the pericycle. *ph.* Phloëm bundles alternating with the bundles of xylem. *p.* Pith, or conjunctive tissue of the stele.

latter, the protoxylem as well as the protophloëm is situated on the outer face of the bundle, so that the development is always centripetal (*fig.* 766, *x*). This constitutes a further important distinction between the root and the stem.

The stele of the root does not usually contain any pith, the xylem bundles becoming united towards the centre. When pith is present the walls of its cells are often lignified, so that the centre of the stele is a hard woody cylinder.

The number of the xylem and phloëm bundles varies, being usually much greater in Monocotyledons than in Dicotyledons. Generally there are as many of one as of the other. When only two of each are present the mass of wood formed by the union of the xylems extends across the cylinder, forming a plate of tissue, and the two bundles of the phloëm lie one on each side of it. Such a root is called ***diarch.*** When more xylem bundles unite to form the plate, corresponding terms are used to describe it; thus we have *triarch*, *tetrarch*, *polyarch* roots. These terms were originally used when it was considered that the central mass of wood was a single bundle, with several points of origination of the differentiation.

The roots of Dicotyledons and Gymnosperms do not contain any meristem homologous with that in the bundles of the stem. When they increase in thickness, they do so by the development of interfascicular cambium, which arises as a secondary meristem in the conjunctive tissue on the inner face of the phloëm bundles, and which forms wood on its inner face and bast on its outer as in the stem. These interrupted strands of cambium are a little later connected together by a similar meristem arising in the pericycle. The cells of the latter divide so as to form two or more layers in thickness behind the primary xylem bundles, and the inner layer becomes merismatic. In this way a sinuous layer of cambium is formed, which becomes circular as growth proceeds. The further development is similar to that of the stem.

The behaviour of the cambium ring is not uniform in different plants. In some it forms wood and bast opposite only to the original phloëm bundles, giving rise to parenchyma behind the primary xylems (*fig.* 767). Thus a broad medullary ray alternates with strands of secondary vascular tissue, as in *Urtica*, *Cucurbita*, and many other plants. This is very prominent generally in fleshy roots. Frequently in the latter, in the width of this ray, separate intermediate strands of vascular tissue occur. In other cases the cambium forms bast and wood opposite to both primary phloëm and primary xylem.

In Monocotyledons and Vascular Cryptogams no cambium layer is developed in the roots, which consequently increase in thickness only very slightly.

Coincidently with the development of the secondary vascular tissue in the stele, a phellogen layer arises, usually in the pericycle, though sometimes in the cortex, which forms cork externally

FIG. 767.

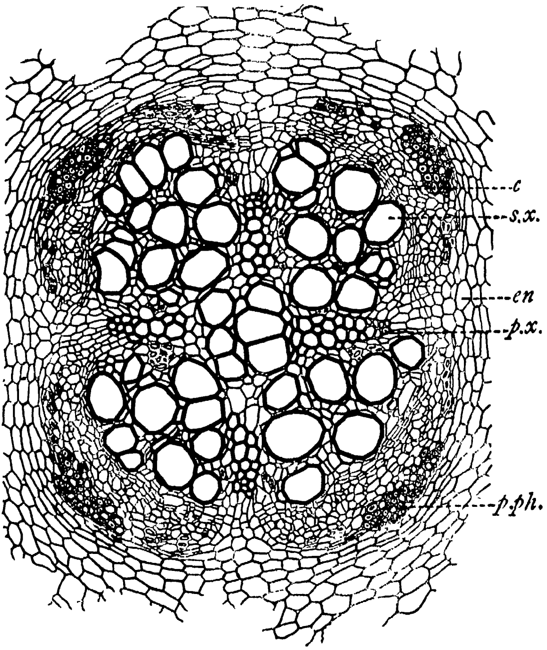


Fig. 767. Section of root showing secondary thickening. *en.* Endodermis. *p.x.* Primary xylem bundles. *p.ph.* Primary phloem bundle. *s.x.* Masses of secondary xylem formed opposite to the latter. *c.* Cambium. Opposite to the primary xylem the cambium has formed parenchyma only, constituting large secondary medullary rays. After Kny.

and phelloderm on its inner face, as in the stem. The tissues external to this periderm formation dry up and are thrown off, so that the exterior of the root is covered by a layer of cork, usually of stelar origin. The phellogen continues active for some time, and then becomes either cork or permanent parenchyma. A new phellogen subsequently arises in the new-formed phelloderm, which behaves as did the first. Later phellogens are successively formed still more internally, till the last-formed one may be separated from the cambium ring by the youngest bast only. In this way a bark is formed in the root very similar in composition to the same structure in the stem. Like that of the stem it often becomes irregularly cracked and fissured; sometimes it is shed annually after the manner of scale bark.

FIG. 768.

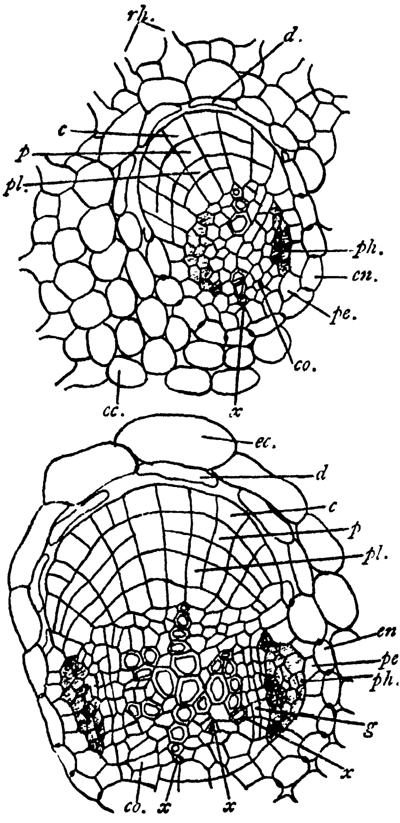


Fig. 768. Transverse section of root of *Hesperis*, to show a rootlet at two stages of development. *rh.* Root hairs. *ec.* Cortex. *d.* Cells in process of absorption. *en.* Endodermis. *pe.* Pericycle. *co.* Conjunctive tissue. *ph.* Phloëm. *g.* Cambium. *x.* Xylem. *c.* Dermatogen of rootlet; *p.* its periblem; *pl.* its plerome. After Van Tieghem. × 250

The branches of the root, like the main root itself, arise endogenously. In all flowering plants they are developed from the pericycle, and bore their way outwards through the cortex.

The number of rows of branches produced from a root corresponds to the number of primary xylem bundles, one being usually formed outside each. At a very early stage in the development of the primary root a group of cells can be distinguished in the pericycle which elongate in the direction of the circumference (*fig.* 768). They divide then by tangential walls, forming a layer two cells deep. The inner one of these is the layer which gives rise to the plerome of the new root. The outer one divides again into two, which are the initial layers of the periblem and dermatogen respectively. The little mass continues to grow, becoming conical, and gradually working its way to the exterior, absorbing by a kind of digestive process the cells of the cortex of the main root as it advances.

If the stele contains more than two xylem bundles, a row of lateral rootlets usually arises at the back of each. If only two are present there are generally four rows of rootlets which are placed in pairs, one a little on either side of each xylem mass. In the Grasses and a few other Monocotyledons they arise opposite to the phloëm bundles, as they do also in some Dicotyledons, where a resin-duct lies in the pericycle behind each xylem bundle.

In most Vascular Cryptogams the meristem of the apex is characterised by the presence of an apical cell (*fig.* 769, *v*). This has the shape of a four-sided pyramid, the base facing outwards. From each face in succession segments are cut off, which by subsequent divisions give rise to the tissue of the root. After each division the apical cell grows to its original size before cutting off the next segment. The segment parallel to the base of the pyramid originates the root-cap, which is a many-layered epidermis, as in the former cases mentioned. The dermatogen in these plants does not produce any part of the covering of the root, the latter being composed of the outer layer of the cortex. The segments cut off from the other faces of the apical cell divide by anticlinal and periclinal walls, forming a mass of tissue in which the limits of periblem and plerome soon become apparent. The innermost layer of the former becomes the endodermis, the outermost layer of the latter, the pericycle, except in certain cases already mentioned, in which this layer is not differentiated. The endodermis is then composed of two layers.

FIG. 769.

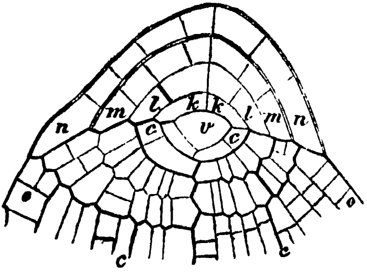


Fig. 769. Longitudinal section through root of *Pteris hastata*, showing apical region. *v*. Apical cell, from which are developed the tissue of the substance of the root, *o*, *c*, and the root-cap, *k*, *l*, *m*, *n*. After Sachs.

The lateral roots in the Vascular Cryptogams do not originate in the pericycle, but in the endodermis. A cell of the latter, which is opposite to a xylem bundle of the main root, cuts out of itself, by four successive divisions, an apical cell which gives rise to the tissue of the lateral root. The latter bores its way through the cortex of the primary root in the way already described. The pericycle takes no part in the formation except to contribute the cells which connect the vessels of the lateral with those of the primary root.

In the *Lycopodiaceæ* no lateral roots are produced; the main root sometimes branches dichotomously, the growing point dividing into two equal ones.

When adventitious roots are formed from the stem, they usually originate in the same way as the normal lateral roots: in the Cryptogams from the endodermis; in the Phanerogams from the pericycle, as already described. In a few rare cases they arise exogenously like the branches of the stem: this occurs when they are developed in connection with adventitious buds.

The so-called *haustoria*, or sucking roots, of parasitic Phanerogams, are developed from the periblem.

The stem and root forming together the axis of the plant, the tissues of the one are continuous with those of the other. The structure is, as we have seen, different in the two parts. Between them there is therefore a region in which the arrangement of the tissues of the one gradually changes into that of the other. This is in the so-called hypocotyledonary portion of the axis, or the part lying between the root and the insertion of the cotyledons. In Dicotyledons the epidermis of the stem is continuous with the piliferous layer, which we have seen is generally the inner layer of the dermatogen, the outer layer of which forms the only true epidermal portion of the root, the root-cap. In Monocotyledons the epidermis of the stem is at first continuous with the epidermis of the root. The latter, however, soon separates and exfoliates with the outer layers of the root-cap, leaving the external layer of the periblem naked. The latter becomes the piliferous layer.

The endodermis and pericycle of the two regions pass directly into each other, and the intermediate cortical tissues are similarly continuous.

The vascular bundles of the root become continuous with those of the stem, but the two constituents change their positions considerably.

In the commonest case each of the xylem bundles of the root divides into two, and the separate halves diverge to the right and left, twisting as they proceed, till the protoxylem, at first on the outer face, becomes internal. The phloem bundles also bifurcate and diverge as do the xylem ones, passing gradually a little towards the exterior. Soon the left strand of a phloem bundle is found to be exactly behind the right strand of the adjacent xylem bundle, the two forming thus an ordinary collateral bundle which passes perpendicularly up the stem. The xylem and phloëm bundles of the stem are thus twice as numerous as those of the root, though by the fusion of the separate strands of bast and wood the number of conjoint collateral bundles of the former corresponds with the number of separate bundles of the latter. The phloëm strands do not twist in their course, so that the protophloëm remains external.

Less frequently the phloem bundles pass straight up into the stem without branching. The xylem bundles branch, diverge and twist as in the former case. The right and left halves of two contiguous xylem bundles meet in front of the continuation upwards of the phloem bundle originally between them, fuse, and become the xylem portion of the conjoint bundle.

In a third case the xylem bundles do not branch, but as they pass upwards twist as before through an angle of 180°. The phloem bundles branch and diverge, the halves of two contiguous ones fusing together behind a xylem bundle and uniting with it to form the conjoint bundle.

In some plants, particularly among the *Rosaceæ*, the roots give rise to adventitious buds. Instead of these being exogenous, as when they spring from the stem, they originate deep in the tissue. They are derived from the pericycle like the lateral roots, and bore their way out in the same way as the latter. *Linaria* shows an exception to this mode of origin, as its radical buds arise from the epidermis.

CHAPTER VI.

THE STRUCTURE OF THE LEAF.

THE leaf, or phyllopodium, arises as a little outgrowth from the stem in close proximity to the growing point (*fig.* 770, *l*). It generally follows in its method of origination the mode of formation of the meristem of the axis; if the latter has an apical cell, the leaf is similarly constructed; if there is a small-celled meristem in the stem, the leaf also has no apical cell. The tissue of the leaf arises from the dermatogen and the periblem, both of which produce a number of cells causing the projection. In further development the dermatogen gives rise to the epidermis, and the periblem to the internal tissue, the plerome of the stem taking no part in its formation.

FIG. 770.

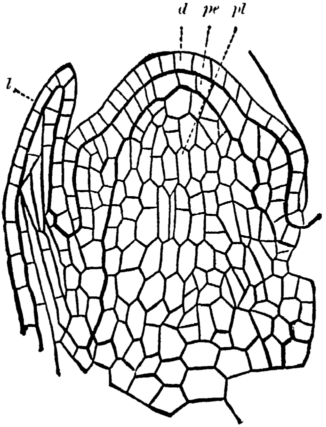


Fig. 770. Growing point of the stem of a Dicotyledon. After Douliot. *d.* Dermatogen. *pe.* Periblem. *pl.* Plerome. *l.* Young leaf. The thick lines are exaggerated to show the limits of the three regions.

Like the stem the phyllopodium may be monostelic or polystelic. In either case the meristeles or separate steles of the leaf become united with the stele or steles of the axis by changes in the cells of the periblem which lie between the axial stele and the insertion of the leaf. The endodermis and the pericycle of the two members become similarly continuous with each other. As the leaf grows, it assumes the shapes already described, by variations in the distribution of growth, part or all of the projection becoming flattened or winged. Usually the three regions described as hypopodium, mesopodium, and epipodium become separately recognisable. The growth is for a time apical, but this soon ceases, except in Ferns, and the further development is caused by basal or intercalary growth.

The structure of the axis of the leaf differs materially from that of the winged outgrowths from it.. In the epipodium the wings are usually much greater in extent than the axis which bears them, so that the structure of the latter is soon lost, and the leaf-blade when seen in section comes to appear altogether different from the rest of the phyllopodium.

The Mespodium or Petiole.—The axis of the phyllopodium is most readily examined in the intermediate region, or petiole, which seldom becomes winged. A section in this region has a somewhat flattened or slightly concave upper surface and a larger convex lower face (*fig.* 772). The same regions can be distinguished as in the stem, viz. an epidermis, a cortex, and a certain amount of stelar tissue.

FIG. 771.

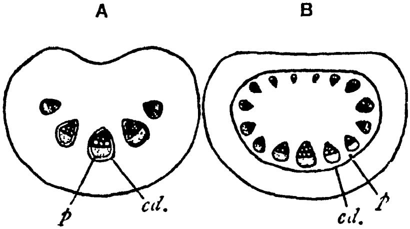


Fig. 771. Sections of two types of phyllopodium. In A the bundles are arranged separately, each having its own endodermis, *ed.*, and pericycle, *p*. In B they are arranged in a ring in the meristele with a common endodermis and pericycle. After Van Tieghem.

The epidermis is similar to that of the stem: its cells are frequently prolonged into hairs; generally stomata are present. The cortex is usually composed of elongated parenchymatous cells with numerous intercellular spaces. Chlorophyll grains are present in the external layers. The tissue is often found to contain hypodermal layers of collenchyma or sclerenchyma, which may be continuous with similar layers in the stem or may be peculiar to the petiole.

In a few leaves, *e.g.* those of *Hoya carnosa*, the petiole contains a layer of cork throughout its length, a little below the epidermis.

If the stem is polystelic in its arrangement, the leaf may receive one or more complete steles from it. Each has then the same structure as that of the axial steles, possessing a pericycle and being surrounded by an endodermis continuous with those of the stem. If the stem is monostelic, each leaf contains one or more steles, usually called *meristeles*, which by subsequent differentiation of the tissue of the periblem of the stem become united with the stele of the latter. The vascular bundles in each meristele may be surrounded by a general endodermis and pericycle (*fig*. 771, B), or the meristele may be replaced in a schizostelic manner by a number of strands, each consisting of a single vascular bundle with endodermis and pericycle enclosing it (*fig*. 771, A). In either case the pericycle very frequently contains a good deal of sclerenchyma, forming strands behind or in front of the bundles. Rarely schizostelic structure is found in the petiole of a polystelic stem, as in *Auricula*.

FIG. 772.

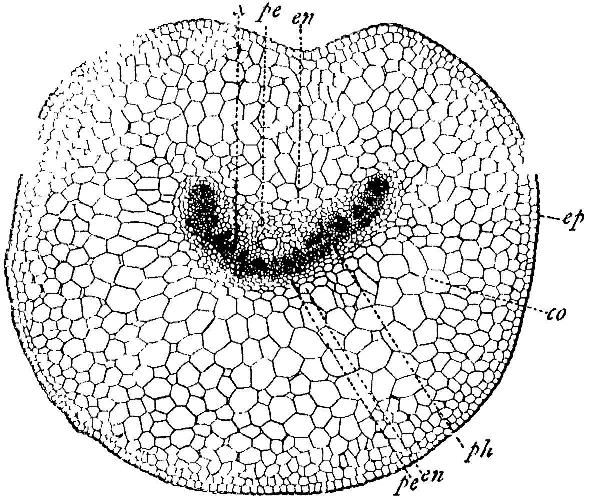


Fig. 772. Mesopodium (petiole) of *Primula* with a single meristele. *ep*. Epidermis. *co*. Cortex. *en*. Endodermis. *pe*. Pericycle. *ph*. Phloëm. *x*. Xylem.

We may find different modes of arrangement of the bundles in the meristele. In the first and most common case they do not form a complete ring, but an arc not closed towards the upper surface (*fig.* 772): hence is derived the term *meristele*. The separate bundles have their bast towards the lower, and wood towards the upper, face of the petiole. They have a common endodermis and pericycle. In the second case there is a complete ring, but the bundles are much smaller on its upper side (*fig.* 771, B). The orientation is then similar to that of the stem, the wood being nearest the centre of the circle, and its development centrifugal.

When there are more meristeles than one in the phyllopodium, the central one is usually the largest. There are frequently three, the two lateral ones being of small dimensions.

The composition of the bundles is the same as that in the stem from which the leaf proceeds, being collateral, bicollateral, or concentric.

In the petioles of *Cycas* the differentiation of the bundles is not the same as that of the stem bundles, the protoxylem of the former being internal but near the outer face, so that the development of the primary wood is mainly centripetal.

Secondary thickening is very rare in the phyllopodium: it does occur, however, in a few families, owing to the persistence of a cambium layer in the usual position in the bundles. The formation of secondary vascular tissue is but slight, and ceases when the leaf has reached its full size. It is less in the lamina than in the petiole.

The hypopodium in deciduous leaves is the seat of a merismatic formation which leads to the separation of the leaf from the stem. A layer of cells extending completely across the phyllopodium, usually exactly at the base of the leaf-stalk, divides several times so as to form a thin sheet of delicate thin-walled cells, and by the absorption of the middle layer of the sheet the two parts become separated and the leaf is cut off. The ruptured surface is found to be covered by a layer of cork.

The Leaf-blade.—When the epipodium of the leaf remains unbranched, it is continuous in a straight line with the petiole if the latter is present. The central axis of the leaf-blade much resembles the petiole, but is rather more flattened. Its lateral margins are continued outwards as a winged expansion. The continuation of the petiole forwards constitutes the *midrib*, and, as might be expected, the structure of the two is essentially similar (compare *figs.* 772 and 773).

The epidermal and cortical tissues are continued onwards from the one to the other without any break, and if the petiole contains bands of collenchyma or sclerenchyma these are found in the midrib also. The vascular bundles send out branches into the wings, the distribution of which varies with the dimensions of the latter.

If the epipodium is branched, the branches may remain distinct or their wings may be fused together to a very variable extent. The secondary axes are generally distinguishable as ribs much like the midrib, and possess a similar structure. If the branching is cymose, there is no main midrib, but several spring from the junction of petiole and blade. As before, these have a structure very similar to that of the petiole.

FIG. 773.

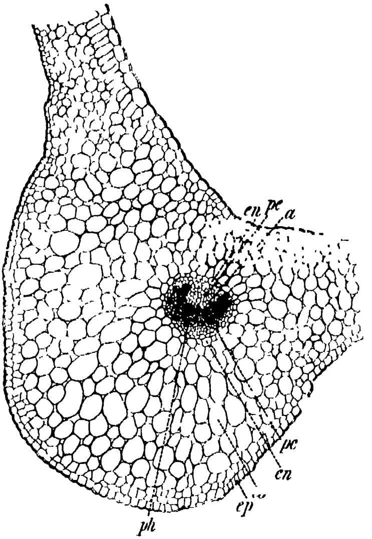


Fig 773. Section of midrib of leaf of *Primula*. *ep*. Epidermis. *co*. Cortex. *en*. Endodermis. *pe*. Pericycle. *ph*. Phloem. *a*. Xylem.

As the termination of the main axis or any of its branches is approached, the axial character becomes less and less conspicuous, till it is indistinguishable from that of the wings with which it is continuous. Where the fusion of the wings has taken place, the vascular bundles from the different axes frequently anastomose with each other, forming a complicated network in which the bundles terminate either separately or in the form of a meshwork.

The transition from the structure of the petiole is thus a gradual one, the successive axes becoming more and more flattened till they lose altogether their cylindrical character. The epidermis is continuous over the whole surface, and is not much altered; the cortex peculiar to the axis becomes gradually replaced by that peculiar to the flattened wings; the vascular elements are gradually attenuated till only a few tracheïds remain conjoined with a limited amount of soft tissue, continuous with the bast. The endodermis of the steles or meristeles can often be traced forwards almost or quite to the termination of the bundles.

The character of the fibro-vascular bundles usually remains unchanged; in most Ferns, however, the originally concentric bundle loses the bast upon its upper face, and so becomes collateral.

The leaf-blade so constructed shows an epidermis which is continuous with that of the petiole, and which extends over the whole of its surface. It is usually only one layer of cells thick; the cells are somewhat brick-shaped on section, and have their outer walls generally cuticularised to a greater or less extent. In thick coriaceous leaves the outer part of the cell-walls of the epidermis can often be stripped off in a continuous layer, known as the cuticle (*fig.* 774). In some leaves the epidermal cells divide by walls parallel to the surface, and the epidermis becomes composed of several layers of cells (*fig.* 775). Viewed from the surface the epidermal cells are sometimes square or oblong, sometimes much sinuated in shape. Generally in the higher plants the cells of the epidermis contain little more than water; in some plants, especially in the Ferns, chloroplasts are present.

FIG. 774.

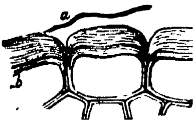


FIG. 775.

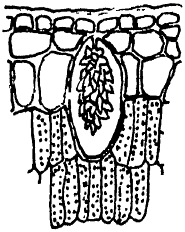


Fig. 774. Vertical section of the epidermis of *Hoya carnosa* treated with caustic potash. *a.* The detached cuticle. *b.* The partially cuticularised layers of the outer walls of the epidermal cells. After Von Mohl. -- *Fig.* 775. Three-layered epidermis of leaf of *Ficus elastica.*

In aquatic plants the external walls of the epidermal cells are not cuticularised.

The epidermis in all the higher plants is furnished with stomata, which are variously disposed. In the leaves of soft herbaceous plants these openings are present on both surfaces of the leaf; those of hard woody plants have them generally only on the lower face; in submerged leaves there are none; in floating leaves they are confined to the upper surface.

In many leaves water stomata are present which remain permanently open. In some, again, there are passages or cracks among the cells, which can hardly be described as stomata. These irregular apertures, like the true water stomata, serve for the emission of drops of water.

In some leaves, as in the Oleander (*Nerium oleander*) and *Banksia*, the stomata are seated in pit-like depressions on the under surface (*fig.* 776).

The cells of the epidermis when the latter is many-layered sometimes contain the cystoliths already described (*fig.* 775).

Within the epidermis of the winged portions of the phyllopodium is the *mesophyll* of the leaf. This is variously arranged, giving two main types of structure, known respectively as the *dorsi-ventral* and the *iso-bilateral*: of these the first is the commonest form (*fig.* 777). It has derived its name from the fact that the tissue is of different character towards the upper and lower surfaces. Immediately under the upper epidermis the cells are oblong, and are arranged with their longest diameter at right angles to the surface of the leaf, constituting the so-called *palisade parenchyma*. The cells contain large numbers of chloroplastids or chlorophyll grains. Sometimes there is only a single layer of these cells, but often there are several. The cells are arranged close together, and have relatively few intercellular spaces among them.

FIG. 776.

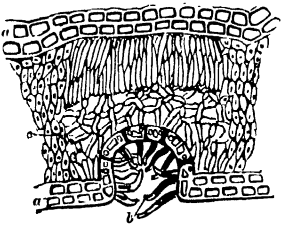


Fig. 776. Vertical section through the leaf of a *Banksia*. *a*, *a*. Epidermis. *c*. Spongiform parenchyma *b*. Hairs which are contained in little depressions on the under surface of the leaf, and at whose base peculiar stomata are found. After Schleiden.

The lower half of the mesophyll is made up of the so-called *spongy parenchyma*. The cells are of irregular shape, and are often arranged so as to be in contact only at portions of their surfaces; the tissue is consequently much less dense, and large intercellular spaces or lacunæ are present: there is always a conspicuous lacuna under each stoma.

The cells of the spongy parenchyma, like those of the palisade tissue, contain chloroplasts; but these are relatively less numerous, causing the under side of dorsi-ventral leaves to appear usually a lighter green than the upper side. In Ferns the differentiation of the mesophyll into these two layers is very feebly marked. The vascular bundles are disposed between the two layers of the mesophyll.

Fig. 777.

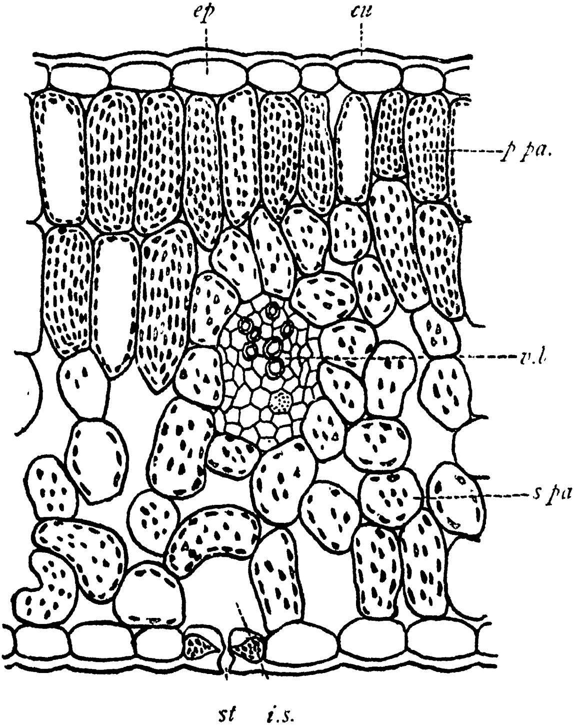


Fig. 777. Section of leaf-blade of *Beta vulgaris*. × 300. *ep.* Epidermis. *cu.* Cuticle, *p.pa.* Palisade parenchyma. *v.b.* Vascular bundle, the xylem being uppermost. *s.pa.* Spongy parenchyma. *st.* Stoma in the lower epidermis. *i.s.* Intercellular space communicating with stoma.

In the iso-bilateral type there are two layers of palisade parenchyma, one on each face. The spongy mesophyll is much less conspicuous, and occupies the space between them. These leaves are frequently supplied with bands of sclerenchyma, which extend from the epidermis inwards, often forming a thick sheath round the bundles, and reaching from one epidermis to the other.

A third type of leaf is characteristic of most succulent plants. The phyllopodium is often cylindrical, and when flattened it can hardly be said to be winged. This is known as the *centric* leaf. Its internal tissue is more or less homogeneous. The cells are usually elongated like those of palisade parenchyma, and have between them narrow intercellular spaces. The chlorophyll is most abundant in the outer layers. Frequently tannin sacs are present. The cells are all very turgid, from the presence of water.

FIG. 778.

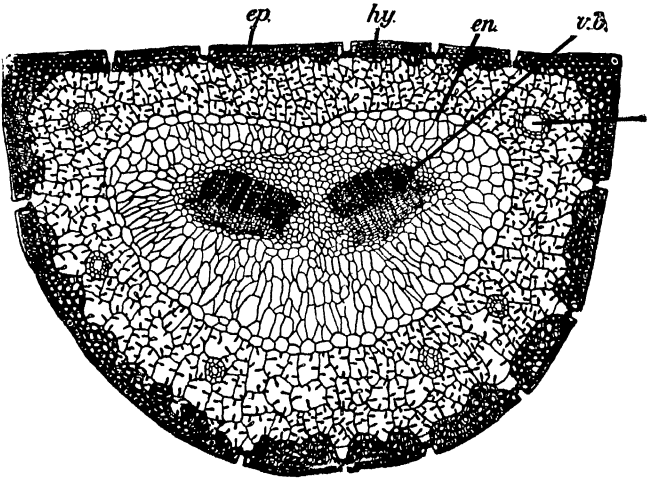


Fig. 778. Centric leaf of *Pinus*. *ep*. Epidermis *hy*. Hypoderma. *en* Endodermis. *v.b*. Vascular bundle. *r.d*. Resin-duct. The mesophyll cells are represented without chloroplasts.

A particular form of the centric leaf is found in some of the Conifers. It is somewhat awl-shaped, and in section appears plano-convex (*fig*. 778). The epidermis is thick-walled and has stomata on all its surfaces, the guard-cells of the latter being usually depressed below the surface. The mesophyll contains a layer of sclerenchyma on its exterior, which at the margins of the leaf consists of a number of cells filling up the angle of the section.

The other cells of the mesophyll are sinuous in outline, and their walls show curious projections of cellulose into the interior. They contain the chloroplasts. In the centre is a well-marked endodermis enclosing a many-layered pericycle and usually two vascular bundles. These are exceptional in containing a layer of cambium between the wood and the bast. The pericycle is also peculiar: it contains a number of tracheids which abut upon the xylem, and serve to convey water from the latter to the mesophyll of the leaf. They are spoken of as *transfusion* tissue. The phloem is in contact with a number of cells containing a somewhat dense protoplasm. Besides these a band of sclerenchymatous fibres is found at the back of the phloem. This transfusion tissue is a special mechanism which is needed in these leaves, as the ultimate ramifications of the vascular bundles are not in apposition with the cells containing the chloroplasts.

The mesophyll of the leaves of the Conifers contains also a variable number of resin-ducts of similar structure to those of the stem.

The vascular bundles of the leaf-blade, as we have seen, are the continuations of those of the axis of the phyllopodium. If the axis is monostelic or polystelic, as the ramifications proceed the bundles ultimately become isolated, and the blade is therefore astelic or schizostelic. Outside the steles or the separate bundles, traceable for a varying distance, is often a band of sclerenchyma or collenchyma, extending in the main ribs to the epidermis of the lower surface. As the bundles are traced further and further from the axis they get thinner and thinner, gradually losing the distinctive characters of their woody and bast elements. The woody part persists furthest, and ultimately consists only of a few tracheids. They end generally in plexuses, or with free terminations among the mesophyll parenchyma. In some cases a peculiar structure, known as a *water-gland*, lies in the mesophyll between the epidermis and the end of the bundle. These bodies consist of a mass of small cells with thin walls, usually covered by a sheath which is continuous with the endodermis of the bundle. The tracheids of the bundle terminate abruptly at the lower end of the gland. One or more water stomata pierce the epidermis over the latter. Sometimes a water-gland is found above a mass of tracheïds formed by the fusion of several bundles.

In certain leaves, especially the bud scales of the Conifers and those of the Horse-chestnut, there is usually a layer of cork underlying the epidermis. The formation of cork is, however, very rare in leaves.

The structure of the outer floral leaves differs but slightly from that of the foliage leaves described. Bracts and sepals are only very little modified, the chief difference being the general absence of sclerenchyma. The upper as well as the lower epidermis, as a rule, contains stomata. When the sepals are fused to form a gamosepalous calyx, sometimes the fibro-vascular bundles of the separate leaves anastomose freely, sometimes they remain independent.

The petals are generally more altered; the epidermis is often papillose and its cells filled with various colouring matters. There is no differentiation of the mesophyll into palisade and spongy parenchyma, and the vascular bundles are much reduced.

The structure of the sporophylls will be best discussed in the succeeding section.

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PREFACE

TO

THE THIRD EDITION

THIS edition is practically the same as the last one. The only change I have made is to use a smaller type for the less important matter, particularly the details of the classification of the different forms of the parts of the flower and fruit.

J. REYNOLDS GREEN.

CAMBRIDGE: *January* 1904.

PREFACE

TO

THE SECOND EDITION

In preparing this edition for the press but few changes have been made. The chapters on morphology have been revised and in some parts compressed. The section on the inflorescence has been rewritten and that on the sexual reproductive organs has been rearranged in view of two years' experience in teaching my classes at Bloomsbury Square, since the adoption of this manual as the text-book there.

Book II. remains practically the same as in the first edition.

J. REYNOLDS GREEN.

CAMBRIDGE: *May* 1897.

PREFACE

THE FIRST EDITION

THIS Manual is intended to take the place of the 'Manual of Botany' written by the late PROFESSOR BENTLEY. Indeed, it was originally contemplated that it should appear as the sixth edition of that work. The chapters on Morphology have been altered only so far as has been necessary in order to incorporate in them the modifications of the older views, which are based upon recent scientific investigations.

While the preparation of this section was in progress the death of PROFESSOR BENTLEY led to considerable alterations in the mode of treatment of the remainder of the book. The subject of the anatomy of plants has been separated from that of morphology and made a separate section. This has been almost entirely rewritten and enlarged, and numerous figures have been added. Many of these are original; others have been borrowed from the writings of contemporary authors.

The old volume being rather too bulky for convenient handling, it has been considered desirable that the present edition shall consist of two parts. In the first of these the subjects of morphology and anatomy of vegetative parts are dealt with; the second will treat of classification and vegetable physiology.

J. REYNOLDS GREEN.

LONDON: *June* 1895.

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